WHAT SCIENCE STANDS FOR

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PREFATORY NOTE

The Blackpool Meeting of the British Association was plainly notable for an awakening sense of social responsibility among English men of science. Certainly the papers on the general theme of the impact of science on the community attracted the most public attention. This book consists of the outstanding contributions to that memorable discussion, being addresses delivered to various sections of the British Association for the Advancement of Science, prepared for publication in book form. It also contains a notable broadcast by Professor A. V. Hill, Secretary of the Royal Society, on "The Humanity of Science."

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I

NUTRITIONAL SCIENCE AND STATE PLANNING

By Sir John Boyd Orr, F.R.S.

A FEW years ago a discussion on the requirements of a diet for human beings would have seemed strangely out of place at a meeting of agricultural scientists, because it was thought that there was not only sufficient agricultural products to meet requirements, but that there was a surplus which could not be consumed. Schemes for bringing prosperity to agriculture were therefore based on controlling production, and limiting the amount allowed to come on the market, with the object of raising prices. The probable effect of a rise in prices on consumption received little attention because it was assumed that owing to the so-called "glut" of food, prices were so low that even if they were raised, people would continue to buy the same amount, and everybody would have sufficient for their needs.

These easy assumptions would have been justified if the function of food were merely to satisfy hunger, because foodstuffs such as wheat and sugar, which can satisfy hunger, have for long been abundant and cheap. With the possible

exception of the very poorest, an ample supply of these has for many years been within the purchasing power of the whole population. But while the application of science to agriculture has enabled us to produce food in greater and greater abundance, and with less and less labour, the advance in the science of nutrition has forced us to accept a new standard of food requirements which is much higher than merely satisfying hunger. According to this new standard there is a shortage of many foodstuffs which are of importance for health, and the cost of the kind of diet now recognized to be needed for health is admitted to be, even in the wealthiest countries, beyond the purchasing power of a large proportion of the population.

The growing demand to get the new science of nutrition applied for the improvement of the health and physique of the nation calls for a reconsideration of the Government agricultural policy initiated by the Agricultural Marketing Acts of 1931 and 1933—a policy which gave farmers producing any foodstuff the right to combine and elect marketing boards with monopolistic powers to control, in the financial interests of the farmers concerned, the production and marketing of that foodstuff. Fortunately, this policy is already discredited. While farmers are justified in taking all legitimate measures to promote their economic interests, the State in

planning must take account of all interests, and obviously the first objective of a State policy must be to ensure that sufficient of the right kind of food is available within the purchasing power of the whole community. In other words, a State agricultural policy must form part of a national food policy, the basis of which must be the provision of a diet adequate for health for every member of the community. From the turmoil and clash of ideas in agricultural planning of the last five years, this obvious and common-sense fundamental principle has emerged and is now finding almost universal acceptance. The starting-point for State planning in the production and marketing of food is, therefore, the requirements for an adequate diet.

The advance in the science of nutrition in the last twenty years has revolutionized our ideas on the requirements for an adequate diet. It used to be assumed that if the diet contained a sufficient amount of protein, fats, and carbohydrates, requirements would be met. Diets were calculated in terms of calories and weight of protein. The calories supply bodily heat and energy for muscular work; the proteins supply material to replace "wear and tear," and in the case of the young, material for the formation of new tissues in growth. According to this rather mechanical conception of the nutritional needs of the body it was easy to assume that if a diet

were palatable and the appetite was satisfied, the needs of the body so far as food is concerned would be met, and any disease or ill-health which occurred could be attributed to heredity or environmental factors other than food. That assumption rather dominated preventive medicine for two or three generations. It is necessary to refer to this old idea of dietary requirements, because until quite recently medical education in practical dietetics was almost wholly limited to what could be expressed in terms of calories and proteins, and assumptions based on their technical training still linger in the minds of some medical men. They are also held by many economists and politicians, who do not realize the extent to which our knowledge of food requirements has increased in the last twenty years.

The discovery of vitamins introduced a new era in the study of nutrition. For a long time the research workers themselves did not realize the importance of the discovery. When, however, it became evident that diets frequently did not contain a sufficient amount of these substances which had been proved to be essential for health, and that indeed there were a number of commonly occurring diseases which seemed to be due to deficiency of vitamins, nutrition began to be studied from a new point of view. The centre of interest moved from quantity to quality, and the different constituents of foodstuffs were studied

to ascertain their influence in maintaining health. In these new studies it soon became evident that diets might be deficient in mineral salts as well as in the newly discovered vitamins. Research was directed to finding out what amounts of the different vitamins and minerals are required for the body under different conditions and the amounts supplied by different foodstuffs.

The new knowledge gained from investigations along this new line of study was applied with spectacular results in the cure of diseases the cause of which had formerly been obscure and mysterious, but which was now proved to be the lack of vitamins and minerals in the food. Modern dietetics is therefore now more concerned with the requirements for vitamins and minerals than the requirements for proteins, fats, and carbohydrates which are essentially the energy suppliers and hunger satisfiers. Foodstuffs rich in vitamins and minerals are relatively expensive, and if the diet contains sufficient of these it is unlikely under ordinary conditions that it will be deficient in energy-yielding constituents which are abundant and cheap.

In researches on the influence of food on health attention was concentrated first upon diseases, such as rickets, which are due to deficiencies either of vitamins or minerals, or both. In experiments with animals, and in clinical observations on human beings, information was

obtained as to the amounts of these required to prevent the appearance of disease. But it became apparent in experiments with animals that there is a wide gulf between perfect health and the condition when obvious signs of disease appear. If an animal has been fed on a diet containing just sufficient to prevent the occurrence of the sign of disease, it may live for a long time and not show any obvious signs of ill-health, but if the diet be improved by making it richer in those substances which prevent disease, it is found that there is a marked improvement in health, vigour, and apparent enjoyment of life. There is thus a higher standard than the absence of obvious disease.

This question of the degree of physical fitness which should be taken as the standard is of the first importance in determining the requirements for an adequate diet. It has been customary to take the average state of health of the community as normal, and regard that as the standard. But dietary surveys have shown that the great majority of diets are deficient to some extent and minor degrees of ill health due to these deficiencies are very common. The average is therefore below the optimum. Children with what are unfortunately regarded as minor defects, such as slight rickets, a slight degree of nutritional anaemia, and carious teeth, might, according to this standard, be regarded as normal. Although they can

run about and attend school, children with these defects are, in fact, suffering from malnutrition due to faulty diet. Numerous large-scale tests have demonstrated beyond the shadow of a doubt that an improvement in the diets of such children is followed by an improvement in health. It is the universal experience that as the standard of living rises with a resulting improvement in the diet, the average physique and health improves. The "normal" of to-day is a higher state of physical well-being than the "normal" of twenty-five years ago. There has been a good deal of futile discussion as to the physical measurements and clinical signs which should be regarded as the indication of a suitable standard of health. The only way to determine the proper standard is to go on improving the diet so long as the improvement is followed by an improvement in health. For public health purposes the standard which should be adopted is a state of physical well-being which cannot be improved by any change in the diet. Anything below that level should be regarded as malnutrition.

In a state of food scarcity we might be glad to have a minimum standard, i.e. a standard above the level at which obvious signs of malnutrition appear. But with the great powers of production which science has given to humanity, and especially when there is a talk of a "glut" of food, we should surely adopt the optimum

standard. If we cannot get it for the whole population, we should for the sake of the future of the race endeavour to get it for mothers and children.

Our knowledge of the exact amount of the different constituents of food required on this optimum standard is still incomplete. Indeed, it will never be possible to state exactly the requirements for any given individual. These vary with age, sex, the amount of work done, the state of housing, hygienic habits, the past history of the individual, and even heredity, for there are important individual idiosyncrasies for some foods. The diet for each individual is a problem for himself. The best we can do is to estimate the average requirements and use these as a guide.

Estimates of the amounts of the various essential constituents of a diet required for health have been made from data derived from experiments on animals and human beings and also from dietary and clinical surveys of large numbers of families. The most comprehensive statement on food requirements for health is that given by Stiebeling in an official report from the United States Government Department of Food Economics. It is unnecessary to give here a table showing the number of calories, the amount of protein and all the different minerals, and the number of units of all the different vitamins. Such a state-

ment is of interest only to technical experts. A statement of food requirements is of general interest only when it is made in terms of foodstuffs. This has been made during the present year by an International Committee of Physiologists appointed by the League of Nations. The method they adopted was to make an arbitrary division of foodstuffs into two groups, first, the protective foods which are rich in vitamins, minerals, and proteins, for example, milk, eggs, fruit, and vegetables, meat and fish, and second, the foods whose chief value is to supply energy and satisfy hunger, e.g. cereals, fats, and sugar. They then set down the amounts of a number of protective foods which, if taken together, will supply all the proteins, the minerals, and the vitamins required. If these be consumed, the health requirements of the diet will be met, and the individual can eat whatever amounts of the energy suppliers of the second group he needs to make up his total energy requirements. Provided the individual is healthy, the amounts of these needed should be determined by appetite.

The report of this Committee has been published and need not be quoted here in detail. As examples of the kind of diets which are adequate for health for different individuals we may take those recommended for pregnant and nursing women, and those for a child of five to seven years of age.

DIETARY SCHEME FOR THE PREGNANT AND NURSING WOMAN

A. Protective Foods

Food	*Amount* grams [1]
Milk	1,000
Meat (or fish or poultry)	120
Eggs (one)	50
Cheese	30
Green, leafy vegetables, e.g. cabbage, lettuce, spinach	100
Potatoes	250
Legumes, dried	10
Cod-liver oil	3·5
Some raw fruit and vegetables.	

[1] 28 grams = 1 oz.

B. Supplementary Energy-yielding Foods

The amounts of the protective foods stated above supply all the protein, vitamins, and minerals required for health. In addition, they supply 1,440 Calories. A pregnant woman needs about 2,400 Calories, and a nursing mother about 3,000 Calories. The additional Calories can be obtained from cereals, fats (butter, if possible), and sugar.

The inclusion of cod-liver oil as an item of diet needs some explanation. Cod-liver oil is the richest source of two of the vitamins which are needed in specially generous amounts by mothers and children. The requirement is increased in winter and under bad housing conditions where there is little sunshine. Under those conditions

it provides a needed additional safeguard to health.

It should be noted that the dietary schedule drawn up by this Committee gives merely an

DIETARY SCHEME FOR A CHILD AGED 5–7 YEARS

A. Protective Foods

Food	*Amount* grams [1]
Milk	1,000
Egg	50
Meat, fish, liver, or cheese	30
Green, leafy vegetables, e.g. cabbage, lettuce, and spinach	100
Potato (and other root vegetables)	150
Cod-liver oil	3
Some raw fruit and vegetables.	

[1] 28 grams = 1 oz.

B. Supplementary Energy-yielding Foods

The above protective foods supply all the protein, vitamins, and minerals required for health, and in addition supply 980 Calories. A child of five to seven needs about 1,430 Calories. The additional Calories can be provided from fat (butter, if possible) and cereals, e.g. bread.

example of the kind of diet which will contain everything required for health. What the Committee did was to take the foodstuffs in common use in Europe and America and draw up in terms of these the kind of diet which would meet the

requirements of the average individual and which would therefore serve as a standard and a guide in practice. Hundreds of different diets containing all that is needed could be drawn up with these foodstuffs in slightly different proportions, or indeed with other foodstuffs not mentioned in these schedules.

Reference should be made here to a report issued by the Advisory Committee on Nutrition appointed about a year ago by the Minister of Health and the Secretary of State for Scotland, to review the national dietary from the point of view of health, and make recommendations for its improvement. After a preliminary survey the Committee felt compelled to issue an interim report calling attention to the need, for health reasons, of increasing the consumption of milk. They recommended that measures should be taken to bring the milk consumption of children up to between one and two pints a day, and of nursing and pregnant mothers up to two pints a day. These amounts are roughly the same as those later recommended by the International Committee of Physiologists. It is probable that when their full report is made, the recommendations with regard to the kind of diet needed for health will correspond closely with that of the International Committee.

The fact that the level of dietary requirements indicated in the specimen diets given in the report

of the International Committee of Physiologists is so far above the average even in such a wealthy country as ours, has brought forth the criticism that this standard is unnecessarily high, and it has been suggested that as it is based only on estimates it cannot be accepted as a reliable guide for practice. Criticisms of this kind were honestly made and deserved full consideration, which, indeed, they received. They were, however, based on assumptions and beliefs acquired from a technical training before the new science of nutrition appeared, rather than on experimental or observational evidence. It is true that the amounts given are estimates. It will never be possible to state to within say 5 per cent the amounts of the various dietary constituents required for any given individual. But these estimates for the average individual under ordinary conditions are based upon an enormous mass of experimental data on both animals and human beings, and on observations on the effect of diets on the health and physique of human beings, and they meet with the general acceptance of the scientific and medical centres in different countries where the subject is being studied. Practical proof of the value of the standard as a guide is afforded by the fact that when the diets in common use amongst the poorer half of the population are improved, health and physique improve, and the evidence so far as it goes seems to indicate that

the improvement in health continues until that standard is reached. These criticisms now carry little weight with those who are studying the effect of food on health. They are, however, well received by certain political and vested interests which would be seriously inconvenienced and embarrassed if there were a widespread demand to bring a sufficient amount of the relatively expensive protective foods within the purchasing power of the poor, and the criticisms are sometimes quoted in a way which was never intended by those who made them, to convey the impression that we have no reliable scientific information which would warrant an attempt to bring the diet of the poorer half of the population up to the standard which the new science of nutrition shows to be necessary for optimum health and physical fitness.

When we compare the kind of diet in common use in this country with the new standard, we find that in the lower income groups the consumption of protective foods is hopelessly inadequate. As income rises the diet approaches closer and closer to the standard. Taking the whole population, however, it is found that the diet of nearly half is below the standard. When the health and physique of different classes are compared, it is found that as income rises and diet improves, health and physique improve. Among the poorest classes with the worst diet, children leaving school

are two to three inches shorter in stature on the average than children of the well-to-do classes, the incidence of diseases due to faulty feeding is more prevalent, infant mortality rate is more than twice as high, and among adults general physique is worse and mortality rate is 50 per cent higher. Of course, other factors, such as heredity and bad housing affect health and physique. The evil effects of bad housing, not only on health, but on moral and spiritual well-being, can hardly be exaggerated. Diet, however, is a predominant factor, as is shown by the fact that there is a marked improvement in health when the diet is improved, although the other conditions are unchanged. Thus, for example, bringing the milk consumption of the children of the poor up to the level recommended is followed by an increased rate of growth approaching that of children of the well-to-do classes, and the increased rate of growth is accompanied by a marked improvement in health.

There has been a good deal of discussion as to whether the deficient diet of the poor should be attributed to poverty or ignorance. Both are undoubtedly to blame. Ignorant and careless housewives, however, are found in all classes, and there is no evidence to suggest that the housewife in the poor homes knows less about food values than her wealthier sister. Indeed, all the available evidence suggests the contrary.

Intelligent and well-informed persons can make a rough estimate for themselves of the extent to which faulty diet is due to poverty. The income of families can be ascertained from e.g. wages, unemployment benefit, and outdoor relief, and the amount available for food can be estimated by deducting fixed charges such as rent and the cost of other necessities. This gives a rough ideal of what is available for food. The cost of a diet on the standard recommended can be calculated. The cost of the one recommended above for a nursing mother is 8s. to 10s. per week according to where and how the foods are purchased. That of a child of five to seven, about 5s. to 6s. per week. For a family with a father, a nursing mother, and four other children, the cost of a diet on this standard would be somewhere between 35s. and 40s. a week. For such a family, the cost of the amount of milk recommended by the Government Advisory Nutrition Committee would be about 15s. a week. Anyone can make a rough estimate of what proportion of the population cannot afford this expenditure on food. This is a calculation which should be made by all those who are interested in political questions. Estimates, even by those who have studied the subject extensively, vary, but it is admitted by all that there is a considerable proportion of the population unable, on account of poverty, to obtain an adequate diet.

This raises what is probably the most important and the most difficult domestic political problems at the present time. In some respects it is merely a new aspect of an old problem which we thought had been solved. Political measures to ensure that every member of the community had sufficient food were framed at a time when it was assumed that it was enough to satisfy hunger. These measures have been effective, for there is now no significant proportion of the population so poor that they cannot purchase sufficient of the energy-yielding foods to satisfy hunger. But the advance in the science of nutrition has rather suddenly set up a new and higher standard of dietary requirements, and we are now at the stage of considering what economic and political measures are needed to enable the new standard to be attained.

Whatever measures are employed will have an effect on our agricultural policy. There is not sufficient protective foods, i.e. fruit, vegetables, and animal products, in the country to bring the diet of everyone up to the standard. The present consumption of milk is less than half a pint per head per day. The new standard demands nearly twice that amount, The average consumption of eggs is about three per head per week. Unless men are to be deprived of their eggs there will need to be increased production to give every mother and child an average of seven per week.

The greatest shortage is in the case of fruit and vegetables. It is difficult to obtain data with regard to the present consumption of these. The available figures, however, suggest that production would need to be more than doubled. There is thus room for a great expansion of British agriculture. But even if the food were produced, there still remains the problem of bringing the retail price within the purchasing power of the poor. It is obvious that a policy of restriction of production and controlled marketing to raise prices must be replaced by a policy of increased production and lowered retail prices.

The production of the additional protective foods needed to bring the national dietary up to the health standard would bring prosperity to agriculture. The increased consumption of these would bring increased health and happiness to the general population. "A diet adequate for health for every member of the community" might well be the common slogan for both agriculture and public health. Further, as the Rt. Hon. Mr. Bruce showed at the Assembly of the League of Nations last September, the marriage of health and agriculture would not only solve our agriculture and public health problems. It would go far to solve the world's economic difficulties, from which we can escape only by increased consumption and a rise in the standard of living.

But we cannot marry health and agriculture

without the gold wedding ring. We cannot get this great advance in public health and development of our agricultural industry without money. This is no insuperable difficulty. Fortunately, we have begun to get a better appreciation of the use of money. We have begun to realize that money spent on works of public utility leaves the country richer instead of poorer. There is no object on which money could be better spent than building a healthy race, expanding our home agriculture and increasing the retail trade in foodstuffs. This can be done. We have the land, the money, and the knowledge to do it. It might be done by developing the present marketing schemes on a national basis for the good of the whole community, instead of on an agricultural basis in the financial interests of farmers. The schemes would need to be given a new objective, viz. to make available at a price within the purchasing power of every household sufficient health foods to bring the diet up to the standard which science says is necessary for health and physical fitness. The reconstituted Marketing Boards would need money from the State. But the State would be buying health and happiness and social content for the poorer half of the population, and at the same time bringing true prosperity to agriculture, and a stimulus to trade. A national food policy on these lines would constitute the greatest social reform of our age.

2

THE HUMANITY OF SCIENCE

By Professor A. V. Hill, SEC. R.S.

THE word "humanity" brings to mind at once the supposed conflict (or at least the supposed contrast) between the humane studies so-called (namely, literature, language, history, and art) on the one side, and science on the other. That conflict, I think, is a complete illusion—as false as the common idea that professors all have long beards, look like nothing on earth, and are absent-minded in their personal habits—as absurd as the notion that no mathematician can do arithmetic—as ridiculous as the libel that women, as a class, drive motor-cars any more dangerously (if that were possible) than men. The truth is that science can be, and should be, and often is one of the humanities.

In a recent series of broadcast talks on various aspects of science the speakers emphasized not only the useful side, the practical side of their researches, but even more the intellectual side, the joy of discovery, the wonder and delight of the knowledge so acquired of the world inside and around us.

Humane culture does not reside only in the

limited past of recorded history/ The methods of science may be used to reveal the details of primitive cultures far older than Greece or Babylon. Nor is there need to wait five hundred years before the ideas and discoveries of the science of to-day become a respectable branch of the humane study of the future. Natural Science is an essential part of a decent education, as essential as literature, history, art, and language; it can offer to the human spirit just as fine a discipline, just as delicate and sympathetic a view of the world. The phrase, "humanity of science," is a claim that science has an equal part with other studies in humane culture. In A. E. Housman's words, "Let us insist that the pursuit of knowledge"—scientific or otherwise, I would add—"like the pursuit of righteousness, is part of man's duty to himself."

In the dictionary "humanity" is first defined as "the quality or condition of being human."

About twenty-eight years ago, during my studies at Cambridge, I read a number of interesting papers in the *Journal of Physiology* by a certain Joseph Barcroft. I had not realized then the "quality or condition of being human" of those who write scientific papers; I supposed that the author of those papers was a learned, respectable, and elderly gentleman. I recall very vividly the astonishment with which one day I suddenly realized the identity of a friendly and humorous

young man who demonstrated to us in our classes. Sir Joseph Barcroft, as he now is, recently told how to get scientific people to work together in teams; he is quite as human as he was in 1908; but I find no difficulty to-day, after twenty-eight years, in realizing that he *is* the author of his papers—indeed, I cannot imagine anyone else as their author! That is because I have learnt, what it has been one of the chief purposes of these talks to show, that the scientist at work is a human being like the rest of us.

Another, an acquired, meaning of the word "humanity" is "kindness or benevolence." Here we may seem to be on more debatable ground, in talking of the humanity of science. The world unfortunately is filled with war and rumours of war. The fruits of science, it appears, may be used chiefly to injure, to exterminate, fellow men. Bombing aeroplanes and poison gas are regarded by many as the most significant products of a scientific age. But science can scarcely be blamed for the misuse which non-scientific people (that is, most of the world) make of certain scientific discoveries. Are we, for example, to forbid long-range prediction of the weather because, if it is successful, it may become easier for some dictator to prepare for an attack on a neighbour? Are we to say that attempts to find out the mechanism of the human ear must be abandoned because the ear may be used in hunting submarines or

locating enemy aircraft? Shall we stop research workers from studying, and so possibly from preventing, plant diseases, because if they succeed too completely or too suddenly an economic crisis may result from over-production of food or tobacco? Are the embryologists' "organizers," which control the development of animals, to be excommunicated because conceivably some day knowledge of them may lead to the control of cancer—and so result in over-population and war? I have no doubt of your answer, at least to this last question: but how—I ask you—is the scientist to know *which* of his discoveries will be misused by wicked or thoughtless men?

We must not take too seriously, then, the war-hysteria of the present time: let us think of things in their proper historical perspective and try to realize what science has actually done. Who would like to think of disease as due to evil spirits? Who wants hundreds of women to die in childbirth of puerperal fever as they did before Pasteur? Who would like to return to surgery before the days of anaesthetics and antiseptics? Who would abolish the transport and machinery by which fresh and healthy food is brought to us cheaply from the ends of the earth? Who that goes on a long journey would like to return to an age when it might be months before he could hear of friends at home? Who indeed, in days to come, would be altogether happy to return to 1936,

when one-eighth of all the deaths are due to cancer, and common prejudice against scientific methods of producing immunity still permits diphtheria to kill many hundreds of children annually? Are the inhumane uses to which science can be put by non-scientific people to be held an objection to the innumerable humane things which science has done, or might do—anyone can think of them—for the betterment, the greater health and happiness and wisdom of men?

I said intentionally and provocatively, "by non-scientific people"; after all, it is government by Parliament or dictator which decides on the use or abuse of any particular discovery: and the number of dictators, or Prime Ministers, or even Members of Parliament, who have acquaintance with science, is still—to put it mildly—insignificant. You cannot blame the inventor of safety matches if a naughty boy uses one to set fire to a haystack!

Another aspect of science which this title might suggest is the degree to which the developments of science are caused by, or directed to, the human needs, the social ideas, the material environment of the time. It is easy for the partisan of any particular political faith to find in history, whether of human thought or of human action, the workings of his pet principles. I doubt personally whether the lives of Newton, Faraday, Clerk Maxwell, or of Leeuwenhoek, Pasteur, or

Pavlov, give support to any particular political creed, unless it be that of tolerance. It is true, all the same, that political, economic, and philosophical ideas, and the human needs of the moment, provide a bias for the work which scientific men do. To take a rather flippant example, one has often heard it said that modern theories of molecules, atoms, and electrons have been given a very distinct bias by the modern habit of playing ball games. Certainly my own work in physiology has been directly influenced by an early interest in athletics. On a more serious plane, Pasteur's discoveries in bacteriology, which have had so great an influence in medicine, were prompted largely by the diseases of silkworms, sheep, and wine which were impoverishing French agriculture. Lord Kelvin's researches were part of the technical and industrial developments of his day. The Royal Institution, where Davy, Faraday, Dewar, and Sir William Bragg have worked, was founded by a movement to improve the condition of the poor. In England in the sixteenth century the expansion of trade and ideas led to the foundation of the Grammar Schools, which are now our Public Schools. In America to-day the same spirit is building universities and research institutions, endowing science, and constructing a two-hundred-inch mirror for an astronomical telescope.

We scientists, therefore, are not unaffected by

social and economic things, any more than we are uninfluenced by the work of others, often in very different fields from our own. The chain of technical events, for example, which is leading to television, has led equally to a knowledge both of the upper atmosphere and also of the workings of nerves and ears. Just as we derive our bodily and mental inheritance, through our parents, from unnumbered others in the past, so the scientific discoveries of to-day are the products, not only of our own efforts, but of the ideas and experiments, the successes and more often the failures, of all those who have preceded us. In this sense the "humanity of science" implies that science is a product of human society; and that its progress depends upon all those ideas, movements, and facilities which are current at any moment in society.

The word "humanity" has one very special sense, pertinent to this talk, namely that of mankind as a whole. Compare the nationalism of politics with the internationalism of knowledge. Of all the interests of mankind there are none so clearly and obviously international as science and learning.

One need not go back far into history for examples. Shortly after the War there was an International Congress of Physiology at Edinburgh. An attempt was made from abroad to exclude the Germans, our late enemies, from

attendance. It was made perfectly clear by a number of British physiologists—people who had taken their part to the full against Germany during the War—that if the Germans were excluded they themselves were not coming. The Germans came, and friendly scientific relations were restored. Similarly, when recent political events in Europe produced a crop of exiles from universities and learned institutions, it was their scientific and other academic colleagues who came at once to their rescue. This chivalrous international tradition, this feeling that science and learning are common factors in humanity, is a very ancient and respectable one; and it is one of the few possible antidotes to the excesses of nationalism at the present time.

Do not imagine that this kind of internationalism implies any lack of affection for one's own country. I am myself an unrepentant internationalist in science, but I very much prefer, perhaps for that very reason, the free democratic institutions of our own country to any of the dictatorships. That preference, however, does not hinder my faith, some would call it a religious faith, in the international spirit of science and learning; or diminish my anxiety to co-operate with genuine scientists in whatever country. Mankind is afflicted to-day by political and economic terrors of his own making. Science has saved him already from many of the worse

terrors of the world in which he finds himself. May not the example of science, with its spirit of friendly co-operation, lead gradually to a more reasonable view of international relationships, and so make its greatest contribution of all to human welfare?

3

THE CHEMIST IN THE SERVICE OF THE COMMUNITY

By Professor J. C. Philip, O.B.E., F.R.S.

Apart from the purely technical side of his work, the chemist's place in the modern community and the kind of training requisite for his profession are of general interest. One aspect of this topic was discussed at the British Association Meeting of 1924 by Sir Robert Robertson, who chose "Chemistry and the State" as the subject of an address. The gradual growth in the official status of the chemist was traced from the point at which he was perforce summoned to assist in the defence of the State to his association in the post-war period with a variety of Government Departments and Government activities. This association has steadily extended in the intervening period, but apart altogether from State activities the science of chemistry and its applications are touching the life of the individual citizen more and more closely every day.

We have, indeed, moved far from the point of view expressed by Lavoisier's judge: "La République n'a pas besoin de savants," but even now there is often in influential quarters an inadequate

grasp of the place and potentialities of the scientist. In the popular mind, and indeed by many who, to judge from their position, should be better informed, the chemist is still frequently associated merely with pharmacy or warfare, in neglect of the innumerable contacts of chemistry with the industry of the country, with the activities of the State, and with the health and comfort of its citizens.

In relation first to those essential activities of any society which is intellectually alive—the pursuit of new learning and the cultivation of the spirit of inquiry—chemistry is in the forefront. For the promotion of natural knowledge and the increase of our understanding of the universe, the chemist has laboured with extraordinary success, both in his own fields and in those borderlands where chemistry marches with other sciences. It is perhaps worth while glancing at one or two of the chief avenues in the region of chemical knowledge opened up by such fundamental research.

While our knowledge of atomic structure is to be credited mainly to the work of physicists, the chemist's technique has revealed the molecular architecture of the most complex natural products, and on the basis of this knowledge the same materials can be synthesized in the laboratory. One has only to think of the sugars, the alkaloids, the anthocyanins, to realize the

astounding results which have been achieved in this field of investigation, while such elusive substances as the vitamins and the sex hormones are rapidly yielding their secrets to the strategy of the organic chemist.

Take again that region in the scale of size which lies between the molecule and the visible particle—the colloid region—the "world of neglected dimensions" as it was once described. In this region, as the physical chemist has shown, the relatively great extent of surface is marked by quite special behaviour, and the labile systems encountered exhibit peculiar characteristics —characteristics which are highly significant for the understanding of physico-chemical changes in the living organism. Our knowledge of this field of surface chemistry is still extending rapidly.

Once more, think of the tracking down of the factors which affect the rate of chemical change and the elucidation of the mechanism of their operation: a little moisture, a speck of dust, a trace of acid, a roughened surface, a ray of light, a rise of temperature: any of these may have a notable influence on the rate of a reaction. The physical chemist has been remarkably successful in unravelling the role of these various factors and in interpreting their significance. It is in such a field as this—the field of kinetics and catalysis—that the progress of chemical science from the qualitative and descriptive way of

treating phenomena to the rational and quantitative has been particularly marked.

These are only one or two of the directions in which the pioneering work of the chemist has opened the way to a fuller knowledge of Nature, especially in the more delicate aspects of her balance and her transformations. In the pursuit of natural knowledge for its own sake, the chemist has indeed travelled far and his exploration has yielded an abundant harvest of discovery. For the pioneer himself it is an adventure, and original research may provide thrilling experiences. All this, however, is far from the common ways of men, and the investigator in the field of pure chemistry moves in a region mostly inaccessible to ordinary folk, and he speaks an unintelligible language, as indeed is true of specialists in other sciences. The so-called "jargon" of science, inevitable as it is to some extent, presents a real difficulty in the transmission of knowledge and ideas from the specialist to the average educated man, but it should not be forgotten that other specialists besides scientific workers have a jargon of their own: to wit, lawyers, financiers, and even sportsmen.

It has been maintained that the pursuit of learning for its own sake is a selfish occupation; that knowledge should be a means to life, not an end in itself, that knowledge is of value only in so far as it leads to action, directly or indirectly.

With this view I have much sympathy, but it has become abundantly clear, so far at least as knowledge and discovery in the realm of pure chemistry are concerned, that we must take a very long view indeed in assessing their practical value. Again and again in the history of the science observations and discoveries have been made, which at the time were of purely scientific interest but which later received important practical applications. The laboratory curiosities of a former generation, such as aluminium and tungsten, have become the industrial commonplaces of the present. The application of exact methods of measuring density revealed the presence of a new gas in the atmosphere—a discovery of purely scientific interest in the first place—which has led to a whole train of remarkable consequences, from a drastic revision of our ideas about the elements to the widespread development of illuminated signs. Just one hundred years ago, at the meeting of the British Association in 1836, Edmund Davy announced the discovery of a "new gaseous bicarburet of hydrogen," now familiar as acetylene. Decades passed, however, before the novel gas acquired any practical significance, and indeed it was not until 1892, when a large-scale method of producing calcium carbide was discovered, that acetylene became of industrial importance. Since then its applications have gone ahead rapidly, and its uses

in illumination, in welding, in metal-cutting, and in the synthetic production of organic chemicals are known to all. In view of these lessons from the history of chemical science one hesitates to apply the epithet "useless" to any specific observation or discovery, however "academic." Reflection indeed suggests that the really big changes in the material conditions of human life have generally had their origin in a search for knowledge on its own account.

There is, however, much more to be said on this matter of fundamental or academic research. A solution of the most practical of chemical problems on rational and scientific lines is possible only because of our accumulated knowledge of natural phenomena and natural laws. It is only against the background provided by the pure research of yesterday that the technical problems of to-day can be viewed in their proper setting and tackled with a reasonable prospect of success. I would submit, therefore, that work in pure science, remote as it generally is from the practical issues of the moment, is building up a real reserve of knowledge and technique on which future generations of practical workers will be able to draw.

Apart from the chemists who are engaged, mostly in our universities and colleges, but to some extent also in the larger research institutes, in the general task of extending the boundaries

of knowledge, there are many more who are carrying on what may be called "directed" research. Their work aims at the solution of some specific problem, concerned, it may be, with the improvement of an industrial process, the elimination of waste, the safeguarding of health, the utilization of by-products, the synthesis of antidotes. More definitely, and by way of example, the object may be to discover a fast blue dye, to purify a water supply, to find a rustless steel, to produce petrol from coal, to isolate a vitamin, to make a non-inflammable film or a creaseless cotton fabric. The general public, however dubious about pure research, would probably admit that the satisfactory solution of any one of these problems would be of service to the community; but it must be emphasized once more that the chemist can do these things only by virtue of his inheritance of knowledge and technique. The attack on such problems, to have a reasonable chance of success, must be organized on the basis of what is already known and what has already been achieved; nay, more, one has abundant ground for belief that the attack, so organized, is bound to succeed, even though it may be "in the long run."

In the last twenty years the amount of directed chemical research in this country has increased enormously. Industries of the most varied description have begun to realize the potential value of

the trained chemist in solving their special problems and putting their manufacturing processes on a more rational basis. In this general movement the State, through the Department of Scientific and Industrial Research, has taken a prominent part by fostering Research Associations. The work of these organizations—such as those dealing with rubber; with paint, colour, and varnish; with cotton or wool; with non-ferrous metals; with sugar confectionery—is in many cases largely chemical or physico-chemical in character. The Research Associations have not only shown how general problems affecting an industry as a whole can be solved by joint research efforts, but their existence and activities have induced a notable degree of "research-mindedness" in the individual associated firms. Financially, the work is based on co-operation between the State and industry, on the principle that the State helps those who help themselves.

The State itself has founded a number of organizations for the study of chemical problems of national importance, and has thus formally recognized the significance of directed research for the community. Six years ago Sir Gilbert Morgan gave an account to the British Association of one of the most notable of these State experiments, namely, the establishing of the Chemical Research Laboratory at Teddington, and the investigation there of various important

problems by a large staff of trained chemists. The work carried out at Teddington has included the study of synthetic resins and low-temperature tars and the exploration of chemical reactions occurring under high pressure, as well as research on metal corrosion, chemotherapy, and water softeners.

Fuel and food are two notable cases in which State-aided investigation is being carried out, and problems connected on the one hand with pulverized and colloidal fuel or the low-temperature carbonization of coal, and on the other with the storage of fruit or the preservation of fish and meat, are being intensively studied at appropriate centres. Reference might be made also to the work of the Building Research Station, where, amongst other matters, the factors determining the weathering qualities of stone are being studied. Other experts than chemists are naturally concerned in the investigation of these problems, but the chemical and physico-chemical aspects are frequently the predominating ones.

Again, the serious question of river pollution has been taken in hand with State help, and some years ago a chemical and biological survey of the river Tees was set on foot, the Tees being chosen for investigation because of the great variety of factory effluents discharged into it both in tidal and non-tidal reaches. Some of the newer industrial developments in Britain are presenting

important problems in this direction. It has been estimated, for example, that if the waste waters from all the beet-sugar factories in this country were discharged into our streams they would cause as much pollution as untreated sewage from a population of four or five millions. The effluents from dairies and factories making milk products present a similar problem. Thanks, however, to research activity, largely at the instance of the Water Pollution Research Board, the disposal or purification of these and other trade effluents is being effectively achieved.

The question of river purification demands for satisfactory handling, as already indicated, the collaboration of other scientists with the chemist, and indeed the attack on many such problems, especially those affecting the health of the community, is likely to be successful only by the co-operation of teams of scientific workers from different fields. Smoke and fog, which not only present the scientist with interesting phenomena but constitute also a social and industrial problem of vital importance, concern the physicist, the physical chemist, the analyst, the fuel engineer, and the meteorologist, and it is only when the knowledge and experience of these workers are pooled that there is any hope of interpreting the phenomena and solving the problem. Again, recent developments in cancer research make it clear that apart from the pathologist, who is

mainly concerned, the chemist has a very definite contribution to make to our knowledge of this baffling disease. Some of the most fruitful scientific investigation, indeed, is co-operative in character.

Research, whether fundamental or directed, is by no means the only outlet for the chemist's knowledge and craftsmanship. The works control of chemical processes, the examination of factory products, the safeguarding of the purity of food, and the supervision of water supplies and sanitation, are examples of other activities of a more routine character in which large numbers of chemists are engaged. These are, so to speak, the general practitioners of the chemical profession, and their contribution to the smooth running of industry and to healthy living is far greater than most people suppose. I have myself been surprised, in a recent survey of the present occupations of my former students, by the extraordinary variety of the work in which chemically trained men may be engaged. This survey shows that photographic emulsions, beer, high-speed steel, printing ink, linoleum, dental cream, gramophone records, bank-notes, and mineral waters are a few of the materials with the production of which the chemist is concerned, either in the laboratory or the works. It is true to say that in the industry of the country the chemist is ubiquitous.

I have referred to the "chemical profession," and the phrase was used deliberately; it is really time that the British public and its leaders recognized the validity and the implications of the term. A profession is a vocation demanding high educational and technical qualifications, and it connotes also the body of those who by virtue of their qualifications are able to serve the needs and welfare of society in some particular field. On all these counts chemistry should have a place beside medicine, law, and engineering. That the public is so slow in recognizing this claim may be due to the fact that the chemical profession is not yet unified to the same extent as the others just mentioned; but it is due also to a lack of realization of the fundamental and widespread character of the service which the chemist renders to the community.

A just estimate of the chemist's function is almost impossible for those who associate him chiefly with explosives and poison gas and regard him as a particularly devilish kind of scientist. Such a picture is hopelessly out of relation with the facts. It is, of course, true that chemists have produced dangerous and poisonous substances, but most of these were discovered originally in the general quest for knowledge, and many have legitimate and valuable applications; their use for destructive purposes is a perversion. Phosgene, for example, one of the so-called poison gases,

was discovered more than a hundred years ago, and is an important material at the intermediate stage in the manufacture of certain dyestuffs. Nitrates, which are the basis for the manufacture of most explosives, play a prominent role as fertilizers in agriculture, and explosives themselves are indispensable in mining operations.

The truth is that the employment for other than beneficial ends of the substances discovered by the chemist is due, not to his especial wickedness, but to the weakness and backwardness of the human spirit. Like other scientists, the chemist normally has a constructive point of view, and he cannot but deplore the fact that, as Sir Alfred Ewing has said: "The command of Nature has been put into man's hands before he knows how to command himself." I believe the vast majority of my fellow chemists dislike intensely the present world-wide prostitution of knowledge and skill to destructive ends. The sooner this is eliminated, and the less call there is for lethal and devastating materials, the greater will be our satisfaction.

There are, indeed, welcome signs that scientific workers are increasingly impatient at the extent to which their knowledge is made to serve inhuman ends. The possibilities before humanity have been fairly set out by a recent historian, H. A. L. Fisher: "The developing miracle of science is at our disposal to use or to abuse, to

make or to mar. With science we may lay civilization in ruins, or enter into a period of plenty and well-being, the like of which has never been experienced by mankind." To the clearing of this conflicting situation, the scientist has not always made the constructive contribution which he might have done: he has been content to adopt an objective and detached attitude, suggesting sometimes complete indifference to the wider human issues at stake. Unfortunately, if one may judge from a recent play by J. B. Priestley, this attitude is commonly regarded as typical of the scientist. Gridley, a ship's engineer, addressing Fletherington, a research chemist, says: "You're all wrong. You're a nuisance. You're a menace. *Fletherington:* I'm not, I'm simply a chemist, a scientist. *Gridley:* I know, I know, and to-day you're trying to blow us up and to-morrow you'll be trying to dose us with poison gas. What do you want to go and make the foul stuff for? Before you've finished you fellows'ull do the lot of us in. *Fletherington:* I'm very distressed to hear you talking like this, Mr. Gridley. I've never willingly hurt anybody in my life. All I do is to research. *Gridley:* Yes, and look at the result. Blowing us up, burning us alive, poisoning us. Just stop your damned research."

This view of research, although it may be crude and ill-informed, nevertheless confronts the scientist with the question whether he is not assenting

too readily to the misuse of his knowledge and skill. Impelled by patriotic motives, most scientists have put themselves freely at the disposal of the State in time of need, but many are hesitating to admit that patriotism must always override considerations of humanity. Whatever be the individual attitude in this matter, it is time for chemists and scientists in general to throw their weight into the scale against the tendencies which are dragging science and civilization down and debasing our heritage of intellectual and spiritual values.

Reference has already been made to the increasing recognition by the State of the value of chemical research, but it is surprising how slowly those responsible for the machinery of government learn to appreciate the real scope of the chemist's work. A comparatively recent instance of the lack of clear thinking on this matter was furnished by the first draft of the formal rules dealing with the manufacture of pharmaceutical preparations containing poisons. Those allowed to control the manufacture were required to possess "qualifications in chemistry," and on this basis general medical practitioners were to be eligible equally with pharmacists and trained chemists. The idea that the general medical practitioner has qualifications in chemistry is ludicrous, and the later drafts of the Poison Rules showed that this had been realized. The contention put

forward in a Home Office Memorandum on these rules that certain operations can be pharmaceutical but not chemical was equally ill-informed.

Inadequate realization of what the chemist even now means for the community and failure to grasp his potentiality for development and progress may have unfortunate consequences in the commercial world. How often is it the case, although there are notable exceptions, that an industrial concern depending essentially on the successful operation of chemical or physico-chemical processes is controlled by a board of directors elected solely by virtue of their financial qualifications. Such men, as a rule, are without real appreciation of scientific method and scientific research, and in the absence of a technical member who can speak with authority on these matters—a technical employee obviously cannot carry the same weight—such a board may make serious mistakes of omission or commission. No amount of financial manipulation, however skilful, can make up for the lack of enlightened scientific control.

If we chemists feel, as we certainly do, that the fundamental and widespread part which our science now plays in the community is not sufficiently realized, and if we consider that our profession should have greater influence in commercial, industrial, and national affairs, the remedy lies to some extent with ourselves, both

individually and collectively. May I suggest that the phrase "serving the community" not only describes what has already been extensively achieved by the chemist, but stands also for a high aim, such as has inspired, for example, the best traditions of the medical profession? The idea of service as a background for life is not new—it is at least 1,900 years old—but I believe it to be true to-day as always that the finest work in any sphere is linked with that ideal. The cynic will, of course, declare that the idea of "service" in the present connection is both sentimental and irrelevant, and that concern for profits and pay need not be tempered with any less material considerations. Against this so-called realism I would urge that the spirit of narrow commercialism and professionalism, without vision of the potentialities of science for humanity, and without concern for the social issues involved, gives colour to the false view that science is anti-social.

Whatever may be our individual views on these questions, practical considerations suggest, and even demand, the formation of a corporate body to represent the common views and stand for the common interests of chemists as a whole. Much has been done already in this direction, but formal unification to the extent which prevails in the medical profession, for example, has not been achieved. The very diversity of the spheres of work with which chemistry is

concerned means that the points of view and the interests of chemists vary widely: the outlook of the public analyst is not that of the research chemist or the man operating a chemical process on the factory scale. It is not surprising, therefore, that progress in the collaboration of chemists has been slow, and it is improbable that the chemical profession can ever become unified as closely and exclusively as the medical profession —even supposing it were desirable.

If for the moment we regard as "trained chemists" all those who have taken an honours degree in Science with chemistry as the principal subject, or who have equivalent qualifications, their number in Great Britain is probably in the neighbourhood of twelve thousand. The majority of these are members of one or more of the three large chartered bodies concerned with chemistry—the Chemical Society, the Institute of Chemistry, and the Society of Chemical Industry. The Chemical Society, which is the oldest of the three and celebrates its centenary in 1941, has had for its chief objects the publication of new knowledge in pure chemistry and the building up of a comprehensive library—aims which have been achieved to a notable extent. The formation of this society took place at a time when the professional and industrial aspects of chemical science were still in the background.

At a later date—over fifty years ago—the Insti-

tute of Chemistry was founded as a definitely professional organization, designed to ensure the possession of adequate qualifications by those engaged in the practice of chemistry. The institute, now the largest of the three chartered bodies, has had a considerable influence on the training of chemists, more especially for consulting and analytical practice, and membership of the organization is, for certain kinds of chemical work, taken as a necessary and sufficient guarantee of professional competence. Unfortunately, however, there is not yet in existence a complete and authoritative register of trained chemists.

The rapid growth of interest in the applications of chemical science led to the formation in 1881 of the Society of Chemical Industry, which aims at the promotion of applied chemistry, by regular publication of relevant information and discussion of the latest developments. The members are linked to one another in Local Sections, which are not confined to Great Britain, and by Subject Groups, which provide a common meeting ground for those interested in Chemical Engineering, Road and Building Materials, Plastics, and Food respectively.

In addition to these three main bodies there are numerous smaller organizations concerned with chemistry in one way or another, such as the Biochemical Society, the British Association of Chemists, the Faraday Society, the Institute of

Brewing, the Institution of Chemical Engineers, or the Society of Public Analysts, and the number of these is in itself a testimony to the variety of the chemist's activities.

Within the last two years a notable step has been taken towards the consolidation of the science and profession of chemistry by the formation of the Chemical Council, which is based on the three chartered organizations already mentioned, as well as on the Association of British Chemical Manufacturers, representing important industrial and commercial interests. The Chemical Council, set up in the first instance for a period of seven years, aims at securing a joint foundation for undertakings which have hitherto been the concern of separate organizations, and at enlisting the support of industry in this matter. The publication of new knowledge, either in the form of original communications or in the form of summaries of papers which have already appeared, is of the first importance in a science growing so rapidly as chemistry. For every chemist, whatever be his particular field of work, some acquaintance with new views, new discoveries, new applications, is essential, and the publication of new knowledge in the appropriate form is really a concern of the whole profession. The successful prosecution of this enterprise is a vital matter also for the industries which depend for their smooth running and their progressive development on the appli-

cation of chemical knowledge and the furtherance of chemical research.

If the newly established Chemical Council can unite the chemical profession and the chemical industry in support of publications and other objects of similarly wide appeal, such as a central library, it will have achieved a notable advance. Its formation is the earnest of further moves in the direction of consolidation and unification of the chemical profession, such as the acquisition of adequate central premises and the establishment of a complete register of trained chemists.

This leads me to consider the kind of preparation which is necessary in order that a man shall be qualified for such registration. The training of chemists, as of other professional men, has for its necessary basis a broad general education for character, culture and citizenship—in the achievement of which the teaching of science can play a distinctive part. Regard for accuracy in observation and in statement, understanding of logical reasoning, interest and delight in the natural world, appreciation of scientific discovery and its meaning for human life—all these are, in some measure at least, within the grasp of the child under the guidance of a live teacher. In this connection it is unfortunate that the elements of biology are taught in comparatively so few schools. It is admittedly easier to arrange for elementary instruction in the physical sciences

than in biology, but, as things are at present, boys, especially, see as a rule only one side of science—they find themselves in a physics-chemistry groove, and this groove may become a rut. My own experience of students from secondary schools (including public schools) proceeding to a university honours degree in chemistry shows that not more than 1 in 12 has had any previous contact with biological science. Apart from the special and intimate relationships between chemistry and vital phenomena, such a state of affairs is regrettable on general and cultural grounds.

After the School Certificate stage our future chemist appropriately begins some specialization in science, either during his last years at school or during his first year at university or college. The special science teaching in secondary schools now reaches in many cases a high level of excellence, but owing to various causes, notably scholarship requirements, the extent of specialization in physics, chemistry, and mathematics during these last two years has become excessive. Not only does this involve a reduction of time and energy for desirable cultural subjects, such as history and English language and literature, but it may mean that the student comes to the university without a mastery of the tools which he will later need in his specialist work. In the case of the chemist this applies especially to the German language, and at the moment we

have the absurd position that many university departments of chemistry are finding it necessary to teach their students German, while the schools on the other hand are busy giving specialist instruction of university standard.

The student who has passed the Intermediate Science stage and who has decided to become a chemist has two or three years' training in front of him before he enters for his final examination. In what way can the most profitable use be made of this time? The attempt to answer this question in detail would be out of place here, but there are a few general considerations which should not be forgotten in connection with this stage in the training of the chemist. In the earlier portion of this address emphasis was laid on the extreme diversity of the tasks which the chemist may be called upon to undertake in his professional career, and clearly, therefore, it is the basic principles of the science that should mainly occupy his attention during his university curriculum. His training must be on broad fundamental lines, and any attempt to plan a university undergraduate course with a view to preparation for some specific chemical occupation, such as paper-making or dyestuff manufacture, is entirely misconceived.

On the other hand, the breadth of the chemist's undergraduate training may be sacrificed to intensive and perhaps excessive study of some

academic aspect of the subject. The criticism is made to-day—and in my view it has some justification—that our graduates in chemistry are weak in their grasp of the fundamentals of the science. It is said that they can talk at length about nuclear spins, valency angles, electron sinks, energy levels, and so on, but are astonishingly uncertain about more elementary and practical matters. The explanation is not far to seek. Discoveries in atomic physics, radioactivity, and other fields have revolutionized the outlook; our basic ideas about matter and energy have been radically altered and extended; chemical properties and reactions have been reinterpreted in terms of the electron and the quantum. The interest and significance of these developments are obvious, and all sound chemical education must incorporate the new knowledge and the new ideas. It does appear, however, that the attempt to present these in all their detail to the undergraduate chemist has involved correspondingly sketchy treatment of less novel, but still fundamental, elements of his training. Further, in the chemical and physico-chemical fields opened up by these new developments there has been a luxuriant growth of theory and speculation, often ephemeral in character, and rendered impressive only by a buttressing of mathematics. A good deal of this enters into the university teaching of chemistry, but much of it has merely

an examination value and contributes nothing to the permanent equipment of the average student—the man whose interests must be kept steadily in view.

The present prominence of this "armchair" chemistry suggests that there is another consideration which academic people are apt to forget. So far at least as the service of the community is concerned chemistry is a practical science and most of the students under training are to be practising chemists. Academic purists may protest that chemistry is a philosophical discipline, not a bread and butter affair, and that anything savouring of vocational training is foreign to the function of a university. It is, however, to the national interest that knowledge and action should be co-ordinated and that our universities should not be divorced from practical affairs. The existence of our Faculties of Medicine and Engineering shows that in other important fields of national service the universities have accepted the burden of putting vocational training on a broad foundation of scientific knowledge. In the training of the chemist, then, knowledge of fundamental principles must be coupled with practical competence, craftsmanship, and technique, and here I would stress the importance of accurate quantitative analysis as one essential element in the education of the chemical student. Apart from its value as enforcing the essentially

exact nature of chemical reactions, experience shows that the successful solution of organic or physico-chemical problems depends in a great many instances on some accurate analytical operation. Laboratory practice and craftsmanship in general, the value of which is discounted by certain schools of physicists to-day, is indeed an indispensable feature of the training of the chemist.

Along with the laboratory I should like to emphasize the importance of the library, and here I refer, not to general university facilities, but to a departmental library, small, it may be, but workmanlike, and run as a real element in the chemist's training. With their eye on examinations many students regard lectures and laboratories as providing the sum total of all wisdom, and yet it is essential that they should have direct access to the original sources of information and learn how to use them. This is best done in a departmental library, accessible and up to date, but success will be achieved only when responsible members of the staff take a real interest in this side of the student's training, and make the library a live affair.

No single science is self-contained and no man can be a chemist without some knowledge and experience of cognate fields. Hence it is appropriate that the undergraduate student of chemistry should study physics or biology, for example, as a subsidiary subject, and this is generally provided

for in the courses which lead to an honours degree in chemistry as the main subject. Where the interval between the Intermediate and the Final Honours Examinations is only two years, time-table considerations unfortunately may forbid the study of more than one subsidiary subject. There is much to be said for a minimum period of three years, which would not only relieve the congestion of a two years' specialist course in chemistry but would enable the student to acquire a broader outlook on related fields of knowledge. In some universities where the three-year interval between Intermediate and Final Honours is in force, the chemistry student takes a general degree—or its equivalent—in three subjects before proceeding to the Final Honours year, and this arrangement has much to commend it.

As to the subsidiary subject or subjects themselves, there should be much elasticity, and the student's own aptitudes and interests should be the determining consideration. Thus while all chemists should have a working knowledge of mathematics up to the calculus, it would be a mistake to make more advanced work in this field obligatory as a subsidiary subject, irrespective of the student's individual capacities and interests. On the other hand, the chemistry student who has a real flair for mathematics—in my experience he is a rare bird—should have every encouragement, both before and after graduation, to culti-

vate his special talent. Such encouragement is specially effective if it is backed by members of the mathematics staff with some appreciation of the chemist's outlook and requirements.

The honours course in pure chemistry which is current in our universities is itself very specialized and, in my judgment, lacks flexibility. Many chemical undergraduates are frankly more interested in the practical application of the broad principles of chemistry than in the refinements and subtleties which figure largely in our honours courses of lectures. Such highly specialized instruction may be appropriate for those who are to spend their lives working in the field of pure chemistry, but it has limited value for those who are less interested in knowledge for its own sake than in its application for practical ends. In physics the necessity of providing for these two types of workers has long been recognized and our universities welcome students of electrical engineering as well as students of pure physics. In view of these considerations serious attention should be devoted to chemical engineering as a degree subject. Experiments in this direction have already been made in one or two places, and the question has been raised afresh by the recent proposal of the Imperial College that an undergraduate course in chemical engineering should be instituted, covering three years after the Intermediate stage. It is essential

that any course such as that proposed should be based on the fundamental principles of physics and chemistry, with the requisite mathematics, and should cover their general application in the field where the chemist and the engineer have common interests and common problems —a field which is very largely that of physical chemistry.

The oft-repeated criticism that the man trained on the lines proposed would be neither a chemist nor an engineer is merely formal and unconvincing; the water-tight separation of the two professions is entirely artificial, for in chemical industrial practice there are many who are primarily chemists but who have to handle large-scale operations on engineering lines. Why should this fact not be faced and the appropriate adjustments made in our university courses of training? It is true that at the present time some men trained in pure chemistry take a post-graduate course in chemical engineering, but this is a piecemeal way of acquiring the relevant knowledge and technique, and the welding of the two disciplines in a balanced curriculum should produce much better results. If the universities will take this matter in hand, the training of the chemical engineer will be moulded on lines consistent with that study of fundamental knowledge which it is the function of the universities to promote.

As in medicine, the man who is at the end of a chemical undergraduate training is only at the beginning of that experience of life and practice which will make him a mature member of his profession. In some cases, depending on aptitude and temperament, it is best that this further experience should be begun outside the university and that the new chemical graduate should at once exchange the comparative calm of academic lecture-rooms and laboratories for the rough and tumble of industrial conditions. These are the cases in which sufficient technical basis is provided in the undergraduate course for a career which will lie more in the field of production management and administration than in that of scientific control and development.

On the other hand, in the majority of cases, the chemist who has just completed his first degree curriculum is well advised to spend one or two post-graduate years at the university, either in research or advanced study, securing in this way the opportunity for more intensive and deliberate work in some special field. While research need not invariably be the occupation of the post-graduate chemist, it is essential that all those with distinct originality and with ambition to extend the boundaries of knowledge should have the chance of learning the art of the pioneer and of experiencing the thrill of discovery. It is from the ranks of such post-graduate workers that the

Davys and the Faradays, the Ramsays and the Perkins of the future must be recruited, and accordingly joint research by staff and students should be a prominent feature of all chemical departments in our universities and colleges. If the investigations proceeding in any one department are of a varied character, so much the better, for where a single field is being explored on established lines, an individual worker may be little more than a cog in a wheel, with only slight benefit to himself.

In the case of those who have no apparent talent or inclination for research, the post-graduate period is more profitably spent in acquiring special knowledge of some particular field. With a thorough undergraduate training in chemistry as a background, intensive work in, say, biochemistry, agricultural chemistry, metallurgy, or the chemistry of food and drugs, provides technical qualifications of a valuable order. At the same time, it must not be forgotten that, however good the post-graduate training in research or advanced study may have been, the chemist will be faced with new problems and new situations when he enters the works laboratory or the factory. This marks the opening of a fresh chapter in his training, and although he may already have acquired a sound knowledge of scientific principles and scientific method, he is but a beginner in other respects, and the new situation may make a

heavy call on his adaptability and common sense. Real achievement at this stage depends largely on character and personality, the possession of which is outside the guarantee of university degrees. For the chemist who has not only intellectual ability and technical competence, but also qualities of leadership and judgment, there is abundant opportunity, and our industries could profitably absorb many more men of this calibre.

Since the war there has been a notable increase in the number of openings for trained chemists and there is a steadily growing demand for such men. It is imperative, however, that the standard of training shall be maintained at a high level with the objects of scientific progress and professional competence always in view. There is no doubt that, given adequate financial and commercial co-operation, chemists trained in our universities and technical schools will be able to meet all demands on their skill and knowledge and to make their full contribution to the industrial and social needs of the community.

Consideration, indeed, of the scientific and industrial developments of the last few decades warrants the view that all technical requirements of the community in goods and services can be met sooner or later. While, however, knowledge and skill increase, wisdom lingers, and it looks as if the real problem at the moment before the

nation—before all civilized nations—is not any difficulty in technical service or technical production, but the wise use and distribution of the natural and synthetic products which science has put at our disposal in such abundant measure.

4

CULTURAL AND SOCIAL VALUES OF SCIENCE

By Sir Richard Gregory, BT., F.R.S.

It is difficult to define "cultural value," for there are many different standards by which it is measured. The term is often used to signify acquaintance with classical languages and literature, but a better view is that learning, whether classical or not, is comprised of many parts, and that culture is the one indivisible whole made up of them. When science is taught, not as an aid to a vocation, but as part of the training of a modern citizen, it may justly be claimed to have a cultural value and to represent modern humanism in the fullest sense. The purpose of scientific study is to discover the truth about all things, including man, his instincts and impulses, his organization in society. The habit of mind developed by this disinterested pursuit may be as effective an ethical agency as that usually associated only with studies of what are called the humanities.

It is, however, common to regard humanism as belonging essentially to polite scholarship or classical learning and having an antipathetic

relation to science. It is true that the introduction of Greek into the curriculum of schools came with the Renaissance movement of the fifteenth century, but that was because the scholars of that period were eager for the new light which the language could reveal. Humanism then meant the substitution of new teaching for old, and its followers aimed at moulding the nature of man as a citizen and an active member of the State rather than at continuing the studies of doctrines relating to the next world upon which the attention of teachers had been concentrated for a thousand years.

The Greek philosophers were the scientific thinkers of their day; and the debt which our own intellectual culture owes to them is unquestionable. Scientific workers do not hesitate to pay tribute to the brilliant genius of Ionian philosophy, the careful work of Hippocrates and his school, and the richness of the Alexandrian epoch. In the teaching of the Ionian school may be found two of the corner-stones of modern chemistry—the existence of elements and the conception of a single fundamental or primordial matter as the source of material diversity. Advanced views relating to the shapes or motions of bodies in the solar system were held at a very early date in Greek history, though they were afterwards superseded by childish ideas; and the first phase of the history of thought upon

organic evolution began with early Greek philosophers in the seventh century before the opening of our era, while its effects on Christian theology and Arabic philosophy were felt for more than two thousand years. Acquaintance with these and other achievements of Greek genius should be part of the intellectual equipment of every educated man, and the science student may find even more to admire in that wonderful age than can the purely literary scholar.

The value of acquaintance with this literature is not in the material knowledge itself, but in the spirit which created it. The Greeks possessed to a high degree the spirit of scientific curiosity and the desire to find a natural explanation for the origin and existence of things which is the ground motive of progress in science. Their aim was the unification of disconnected knowledge. This laid the foundation of synthetic science, but carried with it the tendency to reduce natural phenomena to a rigid geometrical or logical system. It is possible that the modern science student would be all the better if given a trend in the same direction, as experimental inquiry alone is apt to be narrow and must be specialized. Even neglecting this experimental aspect, the early Greek philosophers manifested supremely the characteristics of true apostles of science. Passionate regard for truth, disinterested research, imagination, acute reasoning, and creative intelli-

ce were the essence of their being, and they are elements of the unalterable germ-plasm which transmits the scientific temper throughout the ages.

Cultural and social values are, however, rarely implied with the study of science but with those of literature, history, and other subjects believed to be of a more humane type. Even among scientific workers themselves there are many who are content to regard experimental and observational inquiries as belonging particularly to the natural sciences, and are indifferent to the application of scientific methods to the investigation of social problems or the influence of scientific knowledge upon human thought. Recognition of interrelationships between all departments of learning is, however, becoming more common than it was a generation or so ago; and the forces which were formerly engaged in conflicts between science and religion or science and classics now profess joint interest in the cultivation of all fields of human enlightenment. Evidence of this association of other cultural subjects with science was frankly given in the reports of two important committees appointed by the Prime Minister several years ago to consider the position of English and classics respectively in our educational system. In each of the reports reference was made to the relation of the subject with which it was

particularly concerned to scientific subjects, usually in the spirit of an endeavour to weave them all into a worthy educational fabric. Two extracts from these reports illustrate this tendency to a mutual understanding.

"We have a traditional culture, which comes down to us from the time of the Renaissance, and our literature, which is rich, draws its life-blood therefrom. But the enormous changes in the social life and industrial occupations of the vast majority of our people, changes begun in the sixteenth century and greatly accentuated by the so-called Industrial Revolution, have created a gulf between the world of poetry and the world of everyday life from which we receive our 'habitual impressions.' Here, we believe, lies the root cause of the indifference and hostility towards literature which is the disturbing feature of the situation, as we have explored it. Here, too, lies our hope: since the time cannot be far distant when the poet, who 'follows wheresoever he can find an atmosphere of sensation in which to move his wings,' will invade this vast new territory, and so once more bring sanctification and joy into the sphere of common life."—*The Teaching of English in England* (1926).

"It has been realized that the object of education, on its social side, is to fit a man to play his part in the environment in which he is placed, and that in this environment the forces of nature are not the sole determinant. It is not only on their knowledge of the physical phenomena of the universe that the happiness and welfare of most men depend; they depend rather on their knowledge of the minds and character of themselves and of their fellow men.

But there is no natural antagonism between Science and the Humanities, either in their aims or in their methods. Both set before them, in different fields, the aim of enlarging the confines of human knowledge; both pursue knowledge by observation of facts laboriously gathered, wisely selected and carefully tested; and both in their several ways appeal to the aesthetic sense."—*The Position of Classics in the Educational System of the United Kingdom* (1923).

It is clear that science and literature, or what are called the humanities, are not now regarded by responsible authorities as opposing elements in education. The two terms should be considered as synonymous; for science rightly conceived is modern humanism in its social value. Even if the humanities are understood to mean letters, history, and art, there should be no conflict between these studies and natural knowledge.

But though scientific workers know well enough how science touches art and music, how it may enter into literature, and how it makes history, there is not like appreciation of science from representatives of these schools of thought and teaching. It is commonly assumed that devotion to science inhibits all sense of pleasure in emotional expression, and that familiarity with the structures and processes of Nature breeds indifference to her charms and destroys the aesthetic veil which gives her both mystery and beauty.

The highest gifts in poetry are, however, closely akin to those required for the highest

achievements in science. Some of the greatest poets, Dante, for example, were masters of the science of their time, and Wordsworth, in a famous passage in the preface to his second edition of the *Lyrical Ballads*, looked forward to the time when modern science, having entered into the mental equipment of all cultured men, would inspire a new order of poetry, as philosophy and rural lore inspired Lucretius and Virgil and medieval science inspired Dante. Both orders of mental effort depend upon the imagination, but whereas the man of science uses his imagination to weave events into laws and relations which may be verified and used to predict future action, the poet sees them in their relation to the human soul.

"Poetry," as Wordsworth tells us, "is the wealth and fine spirit of all knowledge. . . . it is the impassioned expression which is in the countenance of all science." It may be added, that whereas science aims at the discovery of pure truth, poetry, having this emotional content aims also at giving pleasure. It implies a certain form and a certain emotional effect, though the substance must also be truth.

While, therefore, science is concerned with ascertained knowledge, the facts themselves are not the material of enduring literature, however brilliantly this may be presented, unless they bear the impress of the discoverer's personality or

strike sympathetic chords in the human heart. That science is continually advancing and revealing new truths is to most people an irritating quality which requires mental effort to be understood. It requires scientific thought to realize the great significance of Kepler's harmonic law of planetary motion, but the words used by him in recording his discovery belong to fine literature because of the human feeling expressed in them. "Let nothing confine me," he wrote in 1618, "I will indulge my sacred ecstasy, I will triumph over mankind by the honest confession that I have stolen the golden vases of the Egyptians to raise a tabernacle for my God, far away from the lands of Egypt. If you forgive me, I rejoice; if you are angry, I cannot help it. The book is written; the die is cast. Let it be read now or by posterity, I care not which. It may well wait a century for a reader, as God has waited six thousand years for an observer."

Another well-known literary gem, revealing a less triumphant spirit of conquest, is that in which Newton saw his great achievements. "To myself," he said, towards the end of his life, "I seem to have been only like a boy playing on the seashore and diverting myself in now and then finding a smoother pebble or a prettier shell than ordinary, while the great ocean of truth lay all undiscovered before me."

These are examples of "literature of power"

as distinct from "literature of knowledge," following De Quincey's division, and they survive because of their human feeling naturally expressed. However lucid the exposition of a scientfic theme may be, therefore, it is not considered to belong to cultural literature unless it represents emotional response to what is perceived or experienced.

In literary circles, indeed, it seems to be believed that the pursuit of scientific knowledge produces a cold and mechanistic type of mind altogether opposed to the throbbing and compassionate heart of life to which literature aims to respond. The knowledge itself is often regarded superciliously because it cannot claim to belong to the eternal verities, even though science can provide hundreds of arresting ideas which await beautiful expression by pen and pencil. With one or two brilliant exceptions, however, popular writers of the present day are indifferent to the knowledge gained by scientific study, and unmoved by the message which science alone is able to give.

Poetry and other forms of literary and artistic expression, once followed more closely on the heels of knowledge than they do to-day. Greek and Roman philosophers often expressed their ideas in verse, and made scientific uses of their imagination. Poetry, philosophy, and science all indeed began life together as children of one

family. The early Greek poets, as Sir Herbert Warren pointed out, like the authors of the Books of Genesis and Job, dealt with the origin of things and the story of creation. The greatest singers of antiquity were the most alive to science.

It cannot be said, however, that the intellectual horizon of men of letters of our own times has been extended by advances in modern science. There is not much evidence in the works of leaders of literature of assimilation of the new knowledge, or even of the slightest sympathy with it. Occasionally, one finds a reasonable attitude towards the age of science and invention in which we live, but more usually there is an absence of an outlook which will regard science not merely as a storehouse of facts to be used for material purposes, but as one of the great human endowments to be ranked with art and religion, and the guide and expression of man's fearless quest for truth.

The influence of science upon material progress and human comfort is understood much more commonly than that of its effect upon the human mind. It is difficult for people of these times to realize the liberation of life and intellect brought about by the works of Copernicus, Galileo, Vesalius, and other pioneers of scientific learning. The very foundations of belief were shaken when it was shown that the abode of man was not the centre of the universe but only a minor

member of a group of planets revolving around a sun which was itself only one of thousands of suns in stellar space.

The Holy Scriptures, together with the works of early Christian fathers and some Greek philosophers, were believed to contain the truth about all things, visible and invisible, and men used them as the final court of appeal as to what was true in Nature. When Galileo discovered the four satellites of Jupiter by means of his small telescope, the philosophers of his time would not look through the instrument to see these bodies for themselves; for, as Galileo remarked, "These people believe there is no truth to seek in Nature but only in the comparison of texts." They held that the moon was perfectly spherical and absolutely smooth, and it was in vain that Galileo appealed to the evidence of observation to the contrary. The sun was supposed to be immaculate; therefore Galileo's observations of spots upon it were illusions. Contrary to philosophic teaching, two unequal masses dropped from the leaning tower of Pisa reached the base together. "Yet," Galileo says, "the Aristotelians, who with their own eyes saw the unequal weights strike the ground at the same instant, ascribed the effect to some unknown cause, and preferred the decision of their master to that of Nature herself."

The principles of self-determination and self-government now accepted as democratic rights

are social effects of the independence of scientific inquiry involved in the new philosophy. The right of a man to think for himself was established, and personal observation and experiment took the place of metaphysical and philosophic speculation and dogmatic assertion. The freedom of thought and action possessed by progressive peoples are direct consequences of the work of Galileo and other scientific pioneers.

When Newton had shown that his law of gravitation was sufficient to account not only for the movements of the planets but also for the paths of the comets, it was no longer reasonable to believe that they were sent as signs or warnings to the human race. Consider the tremendous revolution involved in this substitution of permanent natural law for the conception of a world in which all events were believed to be reflections of the moods of a benign or angry God. The doctrine of daily supernatural intervention meant that men regarded themselves merely as clay in the hands of the potter, and did nothing to shape their own natural destiny. They accepted disease as an Act of God instead of cleansing their houses, and believed that all the qualities they possessed, as well as the actions they took, were determined by the positions of the planets and other celestial bodies. Every organ of the human body was supposed to have its counterpart in the sky, and when Vesalius by his dissections, and Copernicus

by his teaching, showed that there was no relationship between the human frame and the order of the universe, the ponderous superstructure of faith and pseudo-philosophy which had been built upon it fell to pieces, and a new mental world had to be reconstructed. Instead of a few thousand stars supposed to exist to influence the earth and affect the purposes of man, we now know that there are many millions which can never be seen without telescopic aid, and millions more that are not visible with any optical means. The universe has thus been vastly extended and the puerile ideas of past centuries have given place to a far nobler conception of the majesty and power of the Creator.

The intellectual expansion thus brought about, together with the sense of justice which resulted from the knowledge of the existence and permanence of Law in Nature, profoundly influenced human thought and resulted in social changes which had the greatest civilizing effects.

Just as Copernicus deposed the earth from the position it was supposed to occupy in the universe, so Darwin placed man in a new relationship to the rest of living creatures. Indeed, the great controversy between the evolutionists and the creationists in the second half of the nineteenth century corresponded closely with that between the Copernicans and Ptolemaists three hundred years earlier. It is often supposed that Darwinism

leaves ethical and moral ideas out of consideration and stands only for the doctrine of "Nature, red in tooth and claw," but this is due to lack of understanding of the principle. Evolution embodies the idea of social ethics and makes the welfare of the community the essential purpose of the life of the creature. The view that Darwinism signifies nothing more than striving after personal or national mastery at all costs is a crude misconception of this great principle, and was repudiated alike by its founder and by Huxley its most powerful exponent, as contrary to the best ends of civilization.

Science is concerned with the progress of knowledge and the evolution of man not only in the past but also in the present and future. The idea that such development is possible is relatively modern. The chief philosophers of ancient Greece held that the Golden Age was in the past and that mankind was receding from it; and the same view of human decadence is given Biblical authority in Genesis. It is quite possible that some savages have fallen from a higher to a lower level of savagery, but this is an unusual course to follow. We need not believe that man has degenerated from a state of perfect knowledge to that of being "born in sin and shapen in iniquity," or that the recovery of his lost position must be looked for not in this world but in the next. The adoption of the depressing doctrine is opposed

to evolution as a whole and subversive to all progress.

Whether we look to perfection as having been passed long ago or regard it as the promise of the future, the fact that the spirit of man is ever striving to attain it is of particular significance. There is reason for hope when Divine discontent with life as it is urges men to work for higher things.

Unlike the beasts of the field, man can make his own environment and so promote the development of any type he desires to survive—poet, philosopher, profiteer, or pugilist. The social heritage to which he succeeds has an important influence upon his thought and conduct, but he himself can exalt or degrade it.

The advance of science during the past three or four centuries has had supreme social value in the alleviation of human suffering and increase in the capacities and facilities for human happiness. In former days pestilential disease stalked through the world unchecked and took its toll in millions of lives. Plague, or the Black Death, was ascribed to conjunctions of the planets, iniquities of the Jews, Divine wrath, or any other cause but the masterly inactivity of mankind; and it was met by prayer and fasting. Not until 1894 was it proved by Yersin and Kitasato that this dreadful scourge is due to a particular parasite which is conveyed from rats to man by fleas.

The work of Laveran, Manson, and Ross showed that the malarial organism can infect man solely through the bite of a mosquito. Another species of mosquito is responsible for the transmission of yellow fever; Bruce convicted the tsetse-fly as the carrier of sleeping-sickness, while lice are the transmitters of relapsing, typhus, and trench fevers. All this wonderful work is the natural development of Pasteur's researches on the germ theory of putrefaction, Lister's application of it to prevent infection of wounds, and the identification of the microbes of specific diseases by Koch and others.

When nothing is known of the natural laws of a disease, mankind is helpless against it; but when science has discovered the enemy a sound basis can be secured for a plan of campaign to exterminate it. Plague has to be fought by the destruction of rats where it prevails, as well as by better housing and sanitation; malaria and yellow fever have to be kept under control by the continual clearance of breeding-places of mosquitoes in infected areas. Administrative measures based upon the teaching of science have practically abolished plague from the cities of Europe and have cleared Havana, the Isthmus of Panama, the West Indies, and Rio de Janeiro of yellow fever.

Mankind has suffered from malarial fevers from time immemorial, and they still take their

toll of about a million human lives annually, but it was not until the end of last century that their precise cause was discovered and their control made possible. The disease is always due to the invasion of the red blood corpuscles by parasitic organisms, which are extracted by certain common mosquitoes from the blood of persons having malaria, and after passing through stages of development in the body of the insect are carefully injected into the blood of healthy human beings. Malarial fevers were common in Britain not many generations ago, and the "fits of ague" often described as afflicting characters in history were due to them. The disease has become almost extinct in Britain because relatively few people live in districts infected with malarial carrying mosquitoes, and few people also have malaria parasites in their blood for the insects to suck from one person and afterwards inject into another. The particular parasites and the particular mosquitoes may be found producing malarial fevers in any part of the earth where conditions are suitable, but by clearing away the breeding places of the insects within a radius of three or four miles of inhabited areas, the disease can be completely controlled. When these measures have been taken in tropical areas infested with malaria, yellow fever and other diseases formerly supposed to be due to a hot and humid climate, places which had a traditional

terror for Europeans have proved to be just as healthy for them or the native inhabitants as any other part of the earth. As whatever subjects are defined as cultural or humanistic must be understood as being concerned with the welfare of man, the conquest of disease as the result of scientific research may rightly claim a high place among them.

The recovery of classical literature was an important factor in the forces associated with the Revival of Learning, because these masterpieces of antiquity provided points of contact with a stage of human development in which culture or humanism—which had the same meaning—was supreme. New conceptions were involved of the relation of man to Nature, and more liberal views were taken of political, social, and philosophic systems, as well as of human influence and destiny. With this intellectual expansion, but not direct consequences of it, came the use of the mariner's compass and gunpowder, and the invention of paper and printing. These discoveries had profound influences upon the history of civilization; and just as the introduction of "villainous saltpetre" changed the character of war, other applications of science involved new orientations of social conditions. Later the increased use of machinery to displace human labour raised social problems which have now become acute.

The disturbing effects of science and invention were accepted as part of the industrial revolution, but it cannot be said that much sympathetic consideration was given to their human aspects. Little more than a century ago, however, an appeal to the nation made by a body called the "General Association" might be a manifesto published at the present time by the Labour Party or other group of social reformers. The memorial disclaimed any wish to oppose the advantages derived from machinery and scientific advances, but deplored the growth of a system by which manual labour was so much superseded, and the power of production so astonishingly increased, and yet the means of consumption by the majority of the people diminished.

The social conditions of Great Britain were then in a state of transition, as they are now. The principal occupation of the nation was rapidly changing from agriculture to manufacture, and the system in which spinning and weaving were carried on in the domestic life of rural surroundings had given place to the depressing factory system in which workers became parts of the industrial machine. Many people, then as now, wished that a good deal of machinery had never been brought into existence, and looked back with wistful longing to the time when each cottage had a spinning-wheel at its door. To attempt to restrain the advance of science and

invention was, however, regarded by the statesmen of the day as impolitic and impracticable; so while wealth increased and the means of production were multiplied many times, wages diminished and distress became more common than before.

Most of the machinery which now performs a large part of our industrial work, and is supposed to have led to unemployment, did not exist a century ago, yet the poverty of the labouring classes was even greater than it is to-day. The population of Great Britain was then only sixteen millions, yet there were two millions in workhouses or receiving "outdoor relief." The terrible conditions of those days were bitterly described by Carlyle in *Past and Present.* "We have," he wrote, "more riches than any Nation ever had before; we have less good of them than any Nation ever had before. Our successful industry is hitherto unsuccessful; a strange success if we stop here! In the midst of plethoric plenty, the people perish; with gold walls and full barns no man feels safe or satisfied. Workers, master workers, underworkers, all men, come to a pause, stand fixed, and cannot further."

It is little wonder that such bitter fruits of the industrial revolution should have aroused resentment against the life-destroying applications of science, and that even to-day the suggestion should be made to call a halt to discovery or

mechanical improvements which increase production at the expense of labour. A distinction should be made, however, between inventions and machinery which cheapen the production of known commodities and tend, subject to certain reservations, to displace labour, and scientific discoveries which create new demand and absorb labour. While invention deals with means, tools, machines, and appliances, science is concerned with principles, out of which may come the mastery of Nature in the service of man. From Faraday's discovery of the principle of magneto-electricity has developed the whole of the electrical engineering industry, which directly or indirectly has provided employment for millions of workers, and chemical science has been equally productive in the use it makes of human power and knowledge.

Of late years the view has gained ground that skill or craftsmanship, as generally understood, is required in modern industry in ever-lessening extent. Mass production no doubt involves an increase in the amount of unskilled and possibly monotonous work. In the design and manufacture of the intricate machinery by which alone mass production is possible, the skilled workman is, however, finding an ever-widening field. The outlook for the skilled worker is, therefore, not so hopeless as it is sometimes made out to be. It should also be remembered that the

worker himself now demands more of life than in olden days, and so may find routine work less satisfying or intellectually stimulatng than formerly because he himself has changed.

The undoubted increase in the volume of unemployment which has accompanied the means of production may, however, well be regarded as a high price to pay even for the elimination of some of the grosser forms of labour to which in the past men were compelled to submit. To-day, in mines equipped with modern machinery the coal produced is mined with pneumatic picks; and the mine of the future will probably be a brilliantly illuminated underground workshop, operated by electricity, and the miner a skilled mechanic. The magnetic crane enables a workman to operate from a control-house at one time tons of pig-iron which formerly men handled in discomfort, pig by pig. While, however, the facilities for mass production which such inventions afford may add to the welfare and the comfort of the few, they may be dearly purchased by the despair they produce in the displaced worker.

It is, of course, natural that Labour, with its memory of bitter struggles against long hours and low wages, should stress much more acutely the problem of distribution of the products of its toil than that of the factors of industrial progress. The workman has had good reason for

regarding every labour-saving device as a wage-saving device; and it is almost a mockery to suggest to men who find themselves unwanted through the introduction of particular machinery that the ultimate effect will be increased employment. The thought, however sound it may be in industrial economics, affords poor satisfaction for present needs. Men thus displaced through no fault of their own may rightly claim, on the grounds of humanity alone, that the community which is eventually to benefit by the saving in costs of production should accept a measure of responsibility for the maintenance of those whose means of existence have been suddenly taken from them.

Progress in physics and chemistry has indeed profoundly altered those social conditions which it is the purpose of social science to study. In an age when nearly all the problems of administration and development involve scientific factors, the nation cannot afford to leave administrative control in the hands of those who have no first-hand knowledge of science. Modern technical achievement and scientific thought foreshadow a new economic structure for society in which they should be used to exercise decisive influence upon the major policies of the State as well as upon their administration.

Social, economic, and political conditions have been changed by the impact of physical science,

but political economists seem to be unable to adjust these new forces to the rational needs of progressive human life. The immense increase in the productive capacity of mankind is, however, forcing society to consider the human consequences of the unlimited resources now at its disposal. The power production which characterizes the new industrial revolution embodies a profound and vital change in the relation of human labour to the processes and products of the world's work. Greater resources of power and fuller control over the forces of Nature are enabling man to do more and more with less and less human effort. Production has escaped from the limitations imposed by human physical energy, and the invasion of the machine has enabled the world's needs to be supplied with a fraction of the effort formerly used. More and more the function of labour becomes that of admitting power to the machine and manipulating power controls.

It is an ironical comment upon modern civilization that the social reaction to the gifts of plenty thus made possible is not an increase of human welfare, but distress and unemployment. In so far as science has brought about increased productive powers it accepts responsibility for these conditions. It insists, however, that these consequences are not essential, but are due to the neglect of the application of scientific methods

to the solution of social problems. Our distributive and economic system remains on the basis of a pre-scientific era, wholly unadjusted to the change, and unable to bear the burdens placed upon it by the problem of new and almost incredible abundance.

Science has multiplied many times man's power of producing and increasing the fruits of the earth, has facilitated their quick transport, and established easy communication between the peoples of the world, so that civilized man could, if he wished, now make the world one instead of a number of conflicting parts in which statesmen seem to be unable to secure any substantial co-operation. The world has been given everything required for the maintenance of a growing population in a rising standard of comfort, but there are no accepted economic principles for the right use of the new powers, and international agreements are mainly adjustments of national interests conceived in confined political atmospheres and determined by expediency. While this spirit prevails, the prospect of finding a formula which will unite the peoples of the world for industrial and commercial progress and their general well-being seems almost hopeless.

It is obviously useless to attempt to repress scientific discovery and its application to invention, but the State should see that the advantages

derived from the increase of power are used for the benefit of all and not to enrich few to the sacrifice of many. The solution of the social problems created by progressive knowledge is not in the hands of men of science but in those of statesmen and administrators, and unfortunately few of these are familiar with the significance of the factors involved.

It is not suggested that scientific methods applied to the fields of politics, human biology, sociology, economics, and psychology are competent by themselves to solve modern problems. They will enable facts to be ascertained and assembled for consideration by minds free from passion and prejudice, but knowledge of history and insight into human nature will be required to arrive at sound conclusions and to construct practicable policies upon them.

Before a new social order can be built up worthy of the limitless powers which the advance of science has put into the hands of man, the general community and its leaders will have to be persuaded that acquaintance with scientific forces is an essential condition of enlightened government. Without an adequate scientific background it is impossible to evolve a social or political system in which progressive knowledge is used for the widest and best human service. While conditions of life for rich and poor alike have been revolutionized by scientific discoveries and

their application, few statesmen have given serious attention to the social consequences of these developments. It has yet to be understood that the old machinery of government is incapable of weaving the threads provided by modern science into a new social fabric of planned pattern.

Political economists will need to learn new principles of design in order to construct a machine capable of dealing efficiently with the range and strength of the material now available. In social evolution, as in progressive development in the organic kingdom, survival depends upon adaptation to circumstances. Science has created a completely new environment for modern life, but no systematic effort has been made to adapt the social structure to it. What is demanded by the times is a new school of political philosophy in which social problems are studied with the same independence that the experimental philosophers gave to their inquiries into natural phenomena and laws when they revolted against scholasticism three centuries ago. When that new school is established we shall be able to contemplate a new humanism in which increased control of the forces of Nature will be welcomed as a means of increased production with less manual labour and a blessing to mankind rather than be condemned as a social disaster and a menace to civilization.

In recent years, Sir Alfred Ewing, Sir Gowland Hopkins, and other leading representatives of science have warned the world of the disastrous consequences which must ensue unless the gap is lessened between scientific advance and moral or ethical development in both national and international spheres. Though recent events have revealed the practical difficulties in securing co-operation among nations, yet there can be no difference of opinion as to the inhumanity and insane misuse of science in the extension of aerial warfare to the destruction of cities, and the killing and maiming of women and children by poison gas, incendiary bombs, and high explosives, against which the only real defence is retaliation. Unless science repudiates such methods of cultivated barbarism, it must lose whatever right it now possesses to be a spiritual influence and acknowledge with despair that man's ethical evolution has already reached its culminating point. Such an end cannot, however, be contemplated, and it will be avoided by conserving social and spiritual values with scientific teaching and research. With this unity of intention it will be possible to hope for, and expect, scientific guidance of human growth not only towards individual fitness but also towards a higher human perfection.

5

KNOWLEDGE AND POWER

By Sir A. Daniel Hall, K.C.B., F.R.S.

LET us begin by clearing our minds by means of a few definitions. What do we mean by Science? In the first instance science is the response to the curiosity of the human mind regarding man and his environment. Man instinctively wants to know "how the wheels go round." From curiosity and mere speculation he has proceeded to systematic thinking. The development may be without practical outcome, as when speculation about the stars grew into the science of astronomy, or it may result in the building of bridges of non-rusting steel. It mainly originated with the consideration of "things," but inevitably progresses to man himself and his activities and even to the processes of thought in virtue of which science exists. Let me add one more definition or truism—the true aim of science is the enrichment of life. Through science man is obtaining an increased control over the operations of nature and the blind forces which limit his activities.

It has become commonplace to enumerate the gifts of science to humanity during the last century and a half since it began to organize

its forces. We note the progressive extension and speeding-up of communications from sailing-ship to steamboat, from horse-coach to railway, then the motor-car, and now the aeroplane, until we can say we have cast our shoe over the whole world. Science has delivered us from the darkness and cold of the winter within doors, has clothed us in unwonted textiles, is providing us with healthier and more attractive food. It has added to the length of our days and even something to our stature. Above all, it is minimizing the curse of Adam by reducing our dependence upon manual toil. The cultivation of the soil for food constitutes the foundation of civilized life and at one time a man required a week in order to dig an acre. The improvement of the horse plough enabled him to prepare the same area in little more than a day; a modern tractor will make light of it in an hour. It is through this reduction of manual labour that comes the chief impact of science upon social organization.

We usually think of science as concerned with things, and achievements as I have indicated may be dismissed as material only. But think how much science has contributed to the spiritual enrichment of the ordinary man. With travel comes an enhanced understanding of history and enlargement of experience, but though man has always been determined to travel it used to cost him dearly in time and money, as

compared with the facilities now available. Photography and the gramophone can bring the greatest achievements of art and music into the household. And from wireless we should be able to obtain that "awareness" of what is moving in the minds of men which is the mark of the educated man and perhaps a feature most lacking in the English character. I agree that all these gifts are prostituted—that travel becomes deck games and flirtation, that photography becomes snapshots, the gramophone an instrument of torture pervading river and seashore with vulgarity, the wireless a means of blotting out the intelligence in a fog of stunts and variety and jazz, but the potentialities are there. I am now living in a richer, more varied, more colourful world than I was as boy.

Yet for all the paeans with which the progress of science has been accompanied, people are beginning to look at it with distrust. Only in 1927 in a sermon preached during the British Association meeting at Leeds the Bishop of Ripon, Dr. Burroughs, appealed for a ten years' truce in science, a cessation of all discovery until the world could take breath and assimilate what had already been done. Still more recently Dr. Matthews, the Dean of St. Paul's, suggested that men of science should make it a point of honour, a matter of professional ethics, to keep secret any discovery that might be utilized for the pur-

poses of war. I fear the proposal is impracticable. No one can foresee the misapplications of discovery; who could suppose that the internal-combustion engine, by way of the aeroplane, could lead to the bombing of defenceless civilians with poison gas? Moreover, the soldier's "honour" lies in destruction, and in the modern totalitarian State all citizens, men of science included, are soldiers, bound to obey orders even in their thinking. So arises for the men of science one of those conflicts of loyalties with which so many men are confronted to-day.

The fact remains that to many good souls science is taking on the aspects of the enemy, threatening not only the enjoyment of the benefits that it confers but the simpler joys of existence before its arrival. It can be regarded as one of the chief sources of social unrest because while it is increasing the powers of production that suggest the possibilities of something approaching the fundamentals of wealth for all, at the same time it has become the means of broadcasting the knowledge that such opportunities exist and so creating social dissatisfaction and unrest.

The crux of the situation seems to be that while science is conferring upon mankind all this increased power it has given no consideration to whom that power shall be entrusted or to what ends it shall be employed. As we have seen during the last few years, the acceleration of

production has been such as to lead to overstocked markets and widespread unemployment. In the early days of industrialization the access of a new and cheaper commodity always found a stratum of the community previously unsupplied but anxious to possess it and by degrees able to pay the new price. At the same time, however, the organization of industry was on a small scale in relation to a world of consumers. There were dislocations, as when a new invention would displace the older processes, and perhaps for a time plunge an over-specialized town into distress. But nowadays the pace has become killing. Moreover, since the war a new and artificial relation has been set up between production and consumption; the policies of national self-sufficiency have fostered industrialization and at the same time and by the same process deliberately reduced the purchasing power of the peoples, and this over and above the inevitable poverty following upon the destruction wrought by war. Indeed war and the fear of war is the terrible background to all our considerations of social organization. Here, above all, science appears as the enemy, for by its means appalling powers of destruction are being placed in the hands of the governments.

The greatest of all dangers to civilization is the temptation that is now being placed in the hands of the power-mongers. They believe that once

they can obtain control of the machinery they can suppress any further exercise of the popular will. Of old every autocracy degenerated into oppression and was ended by a revolution. But what chance has a popular rising to-day against a Government that possesses machine-guns, bombs, and gas! Revolutions are apt to be successful when popular feeling has grown to such a pitch that the rank and file of the fighting forces turns and joins hands with the people, but it is now likely that other autocracies will lend troops that have no scruples, since they are fighting in a foreign country.

Moreover a subtler technique has been devised, not merely to control men by force but to subdue their minds until they desire to be slaves, mere instruments of their Government. Day by day we see how robots can be created by a Government intent only upon power, which can control the Press and all publications within its country, which can close the frontiers to other communications, which has learnt to utilize wireless and all the machinery of popular advertisement and above all education itself as instruments of propaganda to run people into a mould. The old reformers fought for universal education as the first step towards the liberation of the people from ignorance and poverty; what would be their feelings to-day when they can see education being used to consolidate tyrannies of the

mind as well as the body? We are told that the Germans are moving towards that uniformity of soul and purpose they desiderate in their nation by the sterilization of dissidents. The end that is sought is an ant community of soldiers and workers.

While the ultimate question is whether the fruits of science are to be enjoyed by the whole community or by the few only, there is a preliminary condition to be considered. The knowledge of science itself and of its powers, how far can it become the possession of the community at large or must it remain the attribute of relatively few specialists. It is not a question of privilege, indeed, rather the contrary; on the whole it is the ruling classes of the country—ministers, diplomatists, civil servants, financiers, etc., who lack any real contact with science in their education. In our great public schools the majority of the boys of promise still stick to the old lines of a literary education. Naturally enough, for the intercourse of man with man, "affairs," are carried on by words, but the result is telling heavily against us in a world which is more and more becoming controlled by science. But what do we mean by a scientific education for everyone? It is common form to say that the ordinary man learns to use science without any need of understanding what is behind the mechanism; he has only to press a button or turn a switch. But this

is no valid reproach, the sciences are for the specialists, and even they can only hope to know their own narrow subject. How many Fellows of the Royal Society can give a coherent account of the way their wireless works? None the less, the fundamentals of general science, both physical and biological, are understandable by anyone and should be an essential part of the education of all men and women, and in such training lies our best hope for the future of the race. The specific value of a background of science is that it will encourage, if not create, the habit of acting on reason instead of on emotion. We may recognize that emotion is the mainspring of action and yet believe that reason can exercise some measure of control over the emotions, so that we need not be wholly at the mercy of prepossessions and catchwords. How otherwise has civilization come into being? Everywhere we see individuals and nations responding to crude emotional impulses. Party, Country, Religion are among the greatest and finest incentives to action, but out of them politicians coin the false money wherewith they buy power. All of them are made the sources of the easiest of all self-delusions—that of belonging to a chosen race. Step by step this habit of mind is built up—the old school tie, the club, the regiment, the profession, the social stratum, the nation itself, can and do become dangerous when they are held to confer some superiority unattain-

able outside the group. Each of these loyalties has its noble side and can bring strength both to the individual and the community; none the less they may generate poison in that they foster hatreds of "the lesser breeds without the law." One function of an education based upon science is to destroy this illusion and to teach boys and girls in their earliest formative years that all the world over men and women are, collectively and statistically, very much alike. Diversity exists among the individuals and civilization largely consists in giving that diversity full play.

I repeat that it is from a scientific rather than from a purely literary education that this tolerant, receptive habit of mind is most likely to be acquired. The latter is concerned almost wholly with the past; it pictures the world as the battle-ground of conflicting emotions, it fosters the instinctive desire to reproduce the older order of things and discourages any confidence in the accelerated tempo that science has brought about. But let me not be taken as denying the necessity of a literary education, even its pre-eminence; I am only arguing against its one-sidedeness and its exclusiveness, above all against the ὕβρις it is apt to generate.

But however widely we may spread a knowledge of the scientific method it is not enough; I agree thus far with Dr. Matthews that the working men of science are called upon to organize in order

to make their point of view prevail in the affairs of the State. I recognize how alien this is to the temperament of the leaders of the world of science. They ask only to be allowed to remain in their laboratories, there to secrete knowledge without bothering about its purpose. That they conceive is their function in the community, but in the end such detachment means slavery and the destruction of the freedom of thought upon which science itself depends. Years ago there was an American politician, a candidate for the Vice-Presidency at the time Professor Wilson was running for President. "Brains," he said, "I can buy any of that lot for twenty dollars." And that after all is only a crude way of expressing the attitude of our own governing class—bankers, ministers, civil servants, etc.—to men of science. They are there when they are wanted, and we can always find one to back up our own point of view.

Is there any hope of obtaining a body of men of science who will express a corporative opinion upon public affairs? The existing representative organizations like the Royal Society and the British Association are by charter and custom debarred from participation in politics, and though in the present state of the world's affairs it is difficult to define where politics begin or when they turn into party, it is probably right that both bodies should refuse to express an opinion except when it is invited on some specific matter of science. It is to

be recognized also that many, perhaps the majority of men of science, refuse to claim any greater right than that of the ordinary citizen to an opinion upon affairs, for they feel that their scientific methods can with difficulty be applied to questions which are so little susceptible to weighing and measurement. Again, very few men of science have the time to give to any organization which must precede the expression of any opinion by a rigorous study of the conditions of the problem. In fact the institution for the study of the social aspects of science which I desiderate demands not only a great deal of voluntary work but a permanent staff of investigators. That such an institution is needed I have no doubt. I have more doubt whether it can become effective before the menace of war sweeps aside all other considerations.

6

NATURALISTIC STUDIES IN THE EDUCATION OF THE CITIZEN

By Lancelot Hogben, F.R.S.

THE demand for instruction in the natural sciences as an essential constituent of a curriculum of humanistic studies is not a new theme. It is necessarily the educational creed of any powerful social group or community whose prosperity depends on the application and extension of scientific knowledge. Huxley was its prophet when industrial capitalism was approaching its zenith in mid-Victorian England. It had also been voiced in an earlier phase of capitalistic enterprise, when the Marquis of Worcester wrote *The Century of Inventions*, and Boyle reiterated his eloquent plea that "the goods of mankind may be much increased by the naturalist's insight into the trades." It assumed the dimensions of a nation-wide, though, alas, ephemeral movement when the *Heads of Enquiries* were drawn up by the Invisible College, and was even endorsed by the nation's epic poet. Referring to Milton's brief experience as a schoolmaster in Aldersgate, Johnson remarks in his *Lives of the Poets:*

The purpose of Milton was to teach something more solid than the literature of the schools by reading those authors that treat of physical subjects, such as the Georgick and astronomical treatises of the ancients. . . . But the truth is that knowledge of external nature and the sciences which that knowledge requires or includes are not the great or frequent business of the human mind. Whether we provide for action or conversation, whether we wish to be useful or pleasing, the first requisite is the religious and moral knowledge of right and wrong. . . . Prudence and justice are virtues for all times and all places, we are perpetually moralists, but we are geometricians only by chance. Our intercourse with intellectual nature is necessary: our speculations upon matter are voluntary and at leisure. Physiological learning is of such rare emergence, that one may know another half his life without being able to estimate his skill in hydrostatics or astronomy, but his moral and prudential character appears at once.

To-day the physiological learning of Sir John Orr moves the nation's conscience more than volumes of rhetoric addressed to man's moral and prudential character. Man, in the Machine Age, is a geometrician perpetually, a moralist inadvertently and at leisure. In this matter Johnson was the mouthpiece of the most decadent episode in the social culture of England since Elizabethan times. It is safe to say that there are few remaining educationists who would subscribe wholeheartedly to Johnson's verdict. Most modern educationists sympathize with the claims of natural

science to a place in the education of the citizen and statesman.

It is generally admitted that such instruction will only fulfil its aim if it is extensive rather than intensive. Loading the curriculum with intensive courses in one or another restricted branch of natural science primarily adapted to the needs of pupils destined to become technicians, teachers, and investigators, offers no remedy for the present defects of a humanism which makes no contact with the fundamental features of modern civilization. So much is generally agreed. Differences only arise when discussion gets to grips with the contents of a general course of instruction with this end in view. Everybody has his or her views about what should be selected or rejected from an immense range of possible choice. The trouble is not so much the lack of a programme as a surfeit of conflicting proposals. Weak-kneed compromises from time to time result in a prospectus too vague to provide the basis of a genuine intellectual discipline, or to put it more plainly from the teacher's standpoint, too diffuse to make up a corpus of examinable knowledge.

In striving for agreement it is always well to remember that compromises may be good or bad. Between the two is all that distinguishes a synthesis from a muddle. Bad compromises are the sort negotiated by morally tired people who refuse to take account of fundamental differences,

where such exist. Good ones are accepted on the explicit recognition of their differences by people who are modest and patient enough to abide by the test of practice. To arrive at agreement about the scope of a general course of science taught as part of the curriculum of humanistic studies, it is therefore imperative to make current sources of disagreement as explicit as possible at the outset. It is not enough to see the obvious dangers which arise, because scientific specialists are prone to exaggerate the importance of their personal interests and because sentimental educational reformers are too apt to regard childhood as an end in itself. There will be no solid basis for agreement, unless we accept the fact that education is a social institution with a social function, and that, in consequence, the place of science in education is first and foremost a sociological issue.

That the view of Milton left no perceptible impress on his successors and that the eloquence of Huxley has had little influence on the educational practice of the present day calls for no surprise when we examine each in its own social context. What Professor Clark calls the adventurous hopefulness of Milton's times speedily succumbed in the ensuing stage of monopolistc capitalism. The *Heads of Enquiries* projected in the first years of the Royal Society languished, and the now familiar device of exalting pure

science to the neglect and disparagement of its applications foreshadowed the eclipse which lasted from the death of Newton to the election of Davy. When a Director of the Bank of England appeals to the British Association for a moratorium on inventions we may justifiably wonder whether history is not repeating itself.

Be that as it may, the cogency of Huxley's case has hardly outlived its author. In essence Huxley's plea was moulded in accord with the prevailing doctrine of *laisser faire*. Thanks to science, mankind was now on the threshold of a millennium of prosperity, enlightenment, and peace. Provided that legislators did not interfere with the wheels of industry, expanding knowledge of nature could guarantee expanding vistas of human welfare. The citizen must be taught science to make him realize the felicitous inevitability of orderly progress in a world where the masters of industry competed to exploit the newest discoveries for his benefit. The engaging prospect so unfolded left no space for frozen patents, armament races, chaotic overproduction, mass unemployment, or subsidies to destroy the fruits of the soil.

To-day western civilization is threatened by a widespread reaction against democratic institutions. The cult of virile sentiment and blind obedience to leaders with supposedly superior wisdom now challenges Huxley's robust material-

ism and salutary confidence in the human reason. Our newspapers and bankers are blaming science for the poverty which persists amid the plenty which science has made possible. There is a present danger that public opinion will learn to identify science with the latest horrors of mechanized warfare. We watch with regret the passing of much which was generous and sane in the confident, complacent, and one-sided optimism of Huxley's generation.

If its claims really rest on the belief that advancing scientific knowledge of itself guarantees the continued welfare of mankind, events have stripped away any shred of plausibility for the claims of science to take its place in the education of the citizen and the statesman. The now manifest absurdity of this belief has indeed become the strongest argument for restating the claims of a scientific humanism. If the social consequences of technical progress since their time have failed to fulfil the high hopes of Huxley's contemporaries, the results might well have been anticipated from the dichotomy which they denounced. We have trained a generation of specialists to mind their own business and a generation of statesmen to legislate in ignorance of the technical forces which inexorably control the character of social relations. The men who contributed most to the social framework within which the science of our

own time has attained its present stature were profoundly indifferent to and ignorant of the impact of science on their own handiwork. At a time when cables were carrying messages across oceans Gladstone could ask Faraday whether electricity had a use. Thirty years after the great Liberal leader was dead, the fate of a democracy might depend on forestalling the capture of a radio station by a violent minority.

It is necessary to put the social aspect of the teaching of science forcefully, because so much ambiguity arises when the *cultural* claims of science are put forward. We all know what is meant by the vocational aspect of education, and we wrongly assume that there is equally general agreement about the meaning of its cultural side. In theory the word cultural commonly covers two entirely different functions of an educational system. One is the private problem of helping the individual to discover for himself or herself congenial sources of enjoyment to occupy leisure in later life with the fullest allowance for variety of temperament. The other is the public business of equipping individuals with the knowledge necessary for the discharge of their mutual responsibilities as co-citizens of a democratic society without regard to the personal inclinations of the child. In practice what is called cultural education is neither the one nor the other. Good taste, which is synonymous with

ostentatious refinement appropriate to a leisured class, takes precedence over the cultivation of individual satisfaction of temperamental needs and political rationalizations of a bygone age exclude the study of resources for welfare which a modern community can use or abuse.

The private aspect of education can be, and often is, grossly exaggerated in stating the cultural claims of science in modern education. Fifty years ago, when microscopy was a fashionable hobby for tired business men, there were relatively fewer avenues of vocational choice for people with a personal inclination for scientific pursuits. Presumably there were relatively more misfits among the class of individuals who could choose their means of livelihood. Popular science of a very genuine order could then compete with the novel, drama, golf, and equitation for the entertainment of a type of person who would now encounter few obstacles to a career in science. The brilliant lucidity and simplicity of Faraday's addresses, Ball's lectures, and Huxley's writings have made way for pretentious omnibus productions, and sensational press-cuttings on controversies unintelligible to any but a few dozen specialists are ousting what was once intelligent and, at times, active participation in the progress of science as a pursuit of leisure. Increasing specialization and expanding outlets of vocational choice for individuals with a native inclination or

aptitude for scientific studies must progressively limit the appeal of science as an active hobby.

Meanwhile, the demand of popular educational movements like the W.E.A. is for information about the social problems of our time. That science should be taught, because it teaches children to be observant and curious is a dubious proposition. The case for science as an essential part of the education of the average man or woman does not rest on gratuitous assumptions about the transfer values of particular disciplines, nor on the individual satisfaction which a small class of individuals may derive from verbal disquisitions on the latest, least digested discoveries at the periphery of theoretical research. *The cultural claims of science rest on the social fact that the use and misuse of science intimately affects the everyday life of every citizen in a modern community.*

That there has been substantial progress in linking up the teaching of school science with everyday life must be thankfully admitted, if we compare such new texts as Hadley's *Everyday Physics* with a well-known book called *Statics and Dynamics* as representative of the teaching of physical science thirty years ago. The thanks are due to the efforts of educationists with very little encouragement from scientific specialists in the universities. While such ventures as the Macmillan series are encouraging signs of progress, school teaching in formal science has still much to learn

from such admirable productions as the current *Popular Science Educator* of the Amalgamated Press, which is doing its best to perpetuate Victorian lucidity. School books, even the best of them, are still execrably illustrated, and their design is imbued with the medieval tradition that the function of pictures, if any, is to ornament rather than to expound.

Making the fullest allowance for progress in the teaching of the physical sciences, there is nothing to justify complacency about the introduction of biology into the classroom. The type of instruction imposed on the schools by university specialists is just as academic as the old mechanics of perfectly smooth balls rolling along perfectly flat frictionless slopes. It has few, if any, explicit contacts with the social applications of biological discoveries or with the everyday experience of children brought up in congested urban centres, where the aspidistra, the cat, the dog, and perhaps the plane-tree are the only familiar representatives of the animal and vegetable kingdoms. One is tempted to conclude that the universities have thankfully relinquished the duller parts of elementary courses little changed since Huxley's generation and barely influenced by the vast developments of agricultural production in recent times.

While it is happily true that educationists are ahead of the scientific specialist in so far as the

cultural teaching of science demands emphasis on its place in everyday life, the claims of science in the education of the citizen extend far beyond a passing familiarity with the way in which society at present uses the knowledge available for the advancement of human well-being. What is far more important is a recognition of the potential of human welfare inherent in scientific knowledge which existing social machinery fails to exploit for the commonweal. Even this neglected aspect of the problem which confronts us in designing a general course of science to take its place in the curriculum of humanistic studies does not exhaust all the issues which should claim pre-eminence. Others will emerge more clearly if we consider the dangers with which the preservation of democracy is now faced. One is failure to anticipate the dire penalties we may pay for the misuse of science. Complacent acceptance of its prostitution to destructive ends and ignorance of the constructive alternatives which existing knowledge places at our disposal will have disastrous consequences for all of us if the helplessness and horror of modern war is canalized in a revolt against science, a repudiation of the benefits which science can confer and a retreat to a lower level of civilized living.

In contradistinction to purely static emphasis on the place of science in everyday life to-day, education for citizenship demands a knowledge

of how science is misused, how we fail to make the fullest use of science for our social well-being, and, in short, a vision of what human life could be if we planned all our resources intelligently. It calls for understanding of the way in which social agencies• foster new discoveries and their useful application. In addition it must reinforce confidence in rational endeavour by emphasizing the role of advancing scientific knowledge in the growth of social institutions. This aspect of the cultural claims of science is perhaps least often stated, and there is a peculiar need to state it at the present time. A growing disposition among the adolescent generation to rate rational persuasion and educational methods as exploded liberal superstitions compels us to ask whether western democracy has devised an educational system capable of ensuring its own continuance.

The content of the present curriculum of humanistic studies discloses a sufficiently obvious reason for failure. The teaching of history presents the record of human life as a babel of emotional phrase-making and a panorama of commercial undertakings to the success or failure of which technical progress makes no explicit contribution. If he discusses why the Great Navigations took place when they did, the last thing which the historian generally thinks of asking is what kind of knowledge is needed to steer cargoes over long-distance westerly courses. There are, to be sure,

honourable exceptions like Professor Clark of Oxford. Unfortunately, his interests are not shared by his colleagues, many of whom seem lately to have gravitated away from closer relations with naturalistic studies. Perhaps this is because the study of how inventions are made leads to dangerous thoughts.

Two conclusions follow from the general principles emphasized in the preceding remarks. The first is that a *course of general science adapted to the requirements of citizenship should be orientated towards the elucidation of the major constructive achievements of natural knowledge in the evolution of civilization.* Among the cardinal themes which thus replace the arbitrary division of science into separate "ologies" those which claim special attention are the construction of the calendar, the technique of navigation and map-making, the extension of deep-shaft mining and exhaustion of fuel supplies, the introduction of inanimate and mobile power, the discovery of chemical fertilizers, and the principles of scientific breeding, the control of epidemic diseases, and the national dietetic minimum. School science should not be a selection from the competing claims of specialist disciplines. It should be the story of man's conquest of time-reckoning and space-measurement, of the search for materials and substitutes, the liberation of natural sources of power, and the struggle against hunger and disease. When it becomes this, the

theoretical principles which have the greatest yield will emerge far more clearly, and there will be less reason for disagreeing about the relative importance of different aspects of scientific knowledge.

As a corollary this implies that science for citizenship must be permeated with the historical outlook and taught in the closest association with historical studies. This suggestion must needs run the gauntlet of a powerful, and at the same time pardonable, body of prejudice which is expressed in a recent circular of the Board of Education. It has arisen because of a fashion which was once adopted to enliven the teaching of some sciences, notably chemistry and physiology in the universities. It was called the historical approach because the tedium of the lecture room was from time to time relieved by lantern slides of bearded and very much superannuated scientists or of their birthplaces. Many of us can still recall how serial obituary notices of great uncles who have gone before helped us to return to the matter in hand with redoubled zest. No doubt this method of instruction had the merit of familiarizing students who would not read Professor Pflugel's works with sartorial styles of earlier periods. As it affected our general outlook, it left the impression that science has progressed by a succession of miraculous divinations of exceptionally gifted individuals who might have

contrived to be born at any convenient time with much the same results. Needless to say, biographical anecdotage of this sort throws no light on the relation of science to the changing fabric of social life and their dependence on one another.

In matters affecting educational reform, it is more important to move in the right direction than to move at maximum speed. So no apology is necessary if changes as radical as those contemplated in this discussion cannot be implemented immediately. There is not the social personnel in the universities to supply the requisite training for teachers, still less teachers who could undertake the allotted task in the schools. On the other hand there are welcome piecemeal innovations, which, if duly encouraged, will make it easier to deal with the problem in a few years time. If they seem unimportant in themselves, their collective effect may be significant.

One, which may seem at first sight too trivial to mention, is the provision of special instruction in the teaching of science by a few of our more forward Departments of Education such as Professor Campagnac's at Liverpool. The Departments of Education in our universities have the power to lay the foundations of a new humanism with its roots in the scientific outlook, and incidentally to increase their prestige and importance, if they take the initiative in pressing the claims of the science teacher and his or her

special needs on the Faculties of Science, which at present control the syllabuses.

They would also be well advised to disabuse local education authorities who entertain an undue reverence for the honours degree. To persons who are not well informed about university curricula the epithet signifies a qualification superior to the pass or general degree, as no doubt is true if the end in view is to produce chemists and electricians for industry and biologists for museums and colonial services. In some of our universities the real distinction merely resides in the number of subjects taken. The London honours degree in science and the Oxford Honours School offer a qualification which is disgracefully narrow, if intended to qualify a person to teach science as a cultural subject; and the pass degree at London is at least better than the supposedly higher qualification. Even where there is a wide range of subjects taken, British science degrees are totally inadequate to meet the requirements of a teacher whose main concern is the average citizen rather than the pupil who will eventually specialize for professional scientific work. In the leading British universities there is no provision for instruction in astronomy, unless the student is specializing in mathematics.

This gap in the science teaching of the universities is specially relevant to the considerations which have been advanced, because astronomy

is the oldest of the sciences, and its beginnings are the beginnings of science applied to man's social life. In none of the sciences are the relations of discovery to the social practice of mankind more clearly exhibited, and perhaps no other science is more relevant to information which most educated people have accepted on trust from their childhood onwards. Its neglect is all the more remarkable, because of the close association of astronomy and navigation in the story of Britain's mercantile supremacy. One of the earliest things which most of us learned at school was that certain marks made across a map were called lines of latitude, and that the world we live in is approximately twenty-five thousand miles in circumference. Although considerable time is devoted in schools to a subject called geography, most children still leave the secondary school, and one may venture the guess that most science graduates leave the university, without realizing how a ship's captain determines the latitude of his vessel or hearing of the simple device with which Eratosthenes (250 B.C.) measured the earth's boundary within fifty miles of the true value. Although a child of ten could find the latitude of his house correct to a degree on any clear night with the aid of a plumb-line, a blackboard protractor, and a couple of screws with eyes, most children take latitude, like the Copernican hypothesis, as an act of religious

faith, and curiously enough, if they are Protestants, think it odd that Catholics refused to accept it in the same spirit.

The infusion of a little elementary astronomy into the teaching of geography would raise one of the dullest school subjects to the dignity of a rational discipline, and, incidentally, revolutionize the teaching of elementary mathematics by providing illustrative materials of the class of problems which the more elementary branches of mathematics were designed to deal with. The new departments of geography in the universities could make a welcome and fundamental contribution to the equipment of a social personnel competent to advance the cultural claims of science, if they made a course in the methods and history of cosmography and calendrical practice compulsory for their students and optional for students in natural sciences. Professor E. R. G. Taylor of Birkbeck College is to be congratulated on her initiative in this matter.

Another welcome innovation has taken place at University College, where Professor Wolf has offered a course on the history of science and technology for students of education. In his recently published book on science in the seventeenth century[1] Professor Wolf has broken away from the biographical and obituary school of

[1] *A History of Science, Technology, and Philosophy in the Sixteenth and Seventeenth Centuries.* (London: Allen & Unwin.)

writers who are responsible for so much justifiable prejudice against the history of science, and given us the first comprehensive British work in which the history of science and its applications are dealt with in the same social context. Courses of this kind in the Departments of Education of our Universities and in our training colleges could provide a focus for collaboration between the historian and the man of science. At present there is no common meeting-place. Without one it is impossible to lay the foundations of a genuine scientific humanism. Recently there has been some discussion on the introduction of a course in the history of science at Cambridge. Whether it leads to useful results will depend on whether it is closely affiliated to the teaching of social and economic history or perpetuates the obituary tradition.

The indifference of men of science and educationists in the universities has relinquished one unique opportunity for implementing the cultural claims of science. It was offered shortly after the late European War, when the Civil Service Commission made a paper on *Everyday Science* compulsory for all candidates at examinations for higher grades. Provision of special instruction for such candidates, mainly drawn from the ranks of graduates who specialize in linguistic and historical disciplines, might have provided a nucleus for the training of teachers for

general science as a cultural subject. The examination proved to be a farce, presumably because no such provision was made till last year, when the Commissioners took the retrograde, if comprehensible, course of omitting *Everyday Science* from the list of compulsory papers. The only official recognition of the need for scientific knowledge in the administration of the nation's affairs was thus withdrawn. Such decisions are not necessarily irrevocable, and it is still possible to bring the pressure of public opinion to bear on the Civil Service Commission. If it can be persuaded to reconsider the matter, the British Association would perform a useful service by appointing a joint committee of educationists and men of science to draw up a syllabus of instruction, and urge the universities to provide it.

Whether science will take its needful place in the instruction of the citizen and statesman depends far less on the attitude of the scientific specialist than on that of the educationist. The scientific specialist is too much immersed in his work and too much imbued with an attitude of social indifference generated by a long period of comparative prosperity and security to take an active part in the educational reformation which the present crisis in democratic societies calls for. The problems of the post-war world demand nothing short of a transvaluation of all educational values. Over-specialization is one of the great

obstacles to their solution. If the educationist is to make a constructive contribution to the social problems of the present time, he will have to forfeit the luxury of false modesty in his dealings with the claims of specialists.

The danger is that educationists will seek a remedy by calling on the services of the metaphysician. Fifty years ago idealistic philosophers were content to preserve a lofty neutrality towards scientific questions. The old indifference has now made way for the new impudence of which the following sample is taken from a recent article by Mr. C. E. M. Joad:

> Enclosed within his special compartment the scientist arrives at more or less definite conclusions without stopping to think what relation they bear to the conclusions reached by other scientists working in *their* water-tight compartments. . . . Hence there arises a need of a clearing-house in which the results of the various sciences can be pooled and collated, in order that, looking at them as a whole, we may be able to infer what kind of universe it is that we inhabit. Philosophy is the clearing-house of science. . . .

Such claims put forward by an Oxford philosopher with no pretensions to professional training in science would have been dismissed by Huxley as impertinent rubbish. The picture Mr. Joad presents is a travesty of the facts. All the old landmarks of naturalistic studies are disappearing. The biologist who is a taxonomist must needs

be a geologist. If he is a geneticist he must be something of a mathematician. If he is a physiologist he may be making fundamental contributions to physical chemistry. Physicists are turning chemists, and chemists find themselves wandering into biophysics. The specialization which makes it difficult for the scientist to take a lively and useful interest in his social responsibilities is in part the penalty for the wide range which his technical inquiries cover. Even if he could afford to neglect progress in other disciplines continually encroaching on his special field, he would not expect to gain anything from instruction by specialists in early Mediterranean literature.

Natural science claims a place in the culture of the citizen in the age of hydro-electric power and aviation, because science has changed the world while philosophers have been content to reflect upon it. It is not the glory of science that it can give comprehensive and decisive answers to the questions which Mr. Joad propounds. Any answers it can offer must be hesitating and provisional. The true and lawful goal of science, said Bacon, is that human life be endowed with new powers and inventions. The place of science in the education of the citizen is to enlist him in the constructive task of using the new powers and inventions wisely.

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